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TO DEMONSTRATE THE EFFECTIVENESS OF IODINE FOR THE DISINFECTION OF PUBLIC WATER SUPPLIES AND TO DETERMINE THE PHYSIOLOGICAL EFFECTS ON A HUMAN POPULATION

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Gainesville, Florida

1 March 1968

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Sixth Progress Report

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"To Demonstrate the Effectiveness of Iodine for the Disinfection of Public Water Supplies and to Determine the Physiological Effects on a Human Population"

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March 1, 1968

2. SUMMARY STATEMENT

Two new periods of major pollution of the underground aquifer have been experienced since the submission of the Fifth Progress Report. The first was due to sewage and the second to a highly objectionable industrial waste containing phenolic materials. Because of these occurrences, major emphasis has been placed during the year on extending and refining our laboratory and field procedures and adding additional sampling points and several new chemical determinations. This has made it possible to further identify and evaluate the various physical, chemical and biological factors which are operative in such situations. It has been shown, for example, that pollution may move laterally through the porous limestone formations present in the study area for a distance of three miles in three days, or at the rate of approximately 0.061 ft/sec.

The production of objectionable tastes and odors during the period of experimental iodination of the municipal water supply of Gainesville in 1967 emphasized the importance of a better understanding of the types of compounds which are formed by the reaction of various types of organic compounds present in polluted water with disinfecting concentrations of elemental iodine. Accordingly, two new approaches are being used. One is an extensive series of taste and odor determinations using panels of ten observers. Another is the separation of these compounds in micro concentrations by both distillation and freezing techniques and then identification, where possible, by gas chromatography. Data obtained from the two studies are being correlated. It has been found that the taste threshold concentrations of iodine, free chlorine, and monochloramine are 2.0 mg/l, 0.5 mg/l, and 1.0 mg/l respectively. However, the odor threshold concentrations for the three are in the reverse order, being only 0.06 mg/l for iodine, 0.19 mg/l for free chlorine, and 0.23 mg/l for monochloramine.

Studies of the disinfection of swimming pool water have (a) further demonstrated the effectiveness of iodine as a sanitizing agent, (b) have shown that staphylococci are controlled more effectively by iodine than by chlorine, (c) that organisms other than those now used should be chosen as indicators, (d) that iodine does not control the growth of algae; and (e) that regulatory agencies, in establishing halogen residuals, should specify "free chlorine at pool pH." A simple table providing such values has been prepared and will shortly be published.

Search for an effective algicide continues, employing cultures of specially selected species supplied by Dr. George Fitzgerald of the University of Wisconsin, and a large number of potential new materials, including enzyme inhibitors and a cationic polymer for charge reversal of both the algal cells and the filter medium are being studied. Quantitative studies of eye burn are being carried out, using the facilities of the Eye Clinic of the J. Hillis Miller Health Center.

Studies of the physiological effect of iodine on a human population at the prisons at Lowell, now in their fifth year, continue to indicate

that no undesirable effects have resulted from the ingestion of a water disinfected with a dosage of 1.0 ppm of iodine. While 25 percent of samples of untreated water from one well and 75 percent from the other showed the presence of coliforms, only 3.4 percent of the 384 samples collected from the distribution system since the last Report were positive, far below the permissible limit set by the 1962 Drinking Water Standards. The Lowell studies will be phased out by May or June of 1968 and every effort made, with the cooperation of the Florida State Board of Health, to insure that the operation is continued by the State of Florida as the first permanent installation for the successful disinfection of a public water supply with iodine.

During the fifth grant year, a total of 17 professional and non-professional individuals have carried out the activities outlined in this report; three papers have been presented to professional organizations; five papers have been published; three papers are in press; two papers are scheduled for presentation in 1968; one Bachelor's, two Master's and one Doctor's degree have been awarded to staff members. The two theses and one doctoral dissertation were all based on work done on the grant.

3. CONCISE STATEMENT OF PROGRESS

A. Pollution of Ground Water in the Gainesville, Florida, Area by Sewage

In areas where solution type or karst topography is predominant, short circuiting of ground water is frequently encountered through numerous channels, sinkholes, or even caverns. In such areas the physical, chemical and bacteriological quality of ground water is variable, fluctuating with rainfall and waste disposal practices in the area. Figure 1 is a photograph made in 1964 which shows the second day of development of a small sinkhole on the campus of the University of Florida.

The source of water for the City of Gainesville, Florida, which is derived from an area of typical "karst" topography, has the potential of causing a disease outbreak similar to the one which occurred at Riverside, California, in 1965. Evidence of gross pollution of sewage origin was observed in 1964 and, although corrective measures were taken which eliminated much of the pollution, pollutants derived from both sewage and industrial wastes are present in several of the City's wells.

In our Fifth Progress Report, submitted March 10, 1967, base line studies made up to that date were described and the results of a brief feed of iodine into the municipal water supply were given. Since that time, two new periods of major pollution have been experienced, one due to sewage and one to industrial wastes. These have made it possible to extend and refine our study procedures and to further identify and evaluate the various physical, chemical, and biological factors which are operative in such situations; to suggest methods for the prevention and control of such pollution; and to locate sites within the study area where new wells might be drilled with minimum danger of future pollution. A small amount of material from the Fifth Progress Report, including Figures 2 and 3, has been used to provide continuity and to aid in the interpretation of the large amount of new data given in this Report.

Floridan Aquifer

General Characteristics - The City of Gainesville is located over one of the most productive ground water formations in the continental United States. This formation, called the Floridan Aquifer, underlies most of the Florida peninsula with numerous recharge areas and sufficient head to prevent serious salt water intrusion. It is the primary source of fresh water for Florida and serves as the source of water supply for most municipalities. This aquifer is the source of water supply for the City of Gainesville.

In the Gainesville area, the Florida Aquifer is composed primarily of limestones and dolomites to a depth of several thousand feet. The cover of sands and clays extends from the surface to a depth of about 150 feet, becoming thinner to the southwest and thicker to the northeast. The aquifer can be considered as being primarily composed of three strata as follows:

Fig. 1 - Birth of a Sinkhole.

This photograph, made on March 19, 1964, shows the second day in the formation of a sinkhole on the campus of the University of Florida. Lake Alice is in the background.

1. An upper permeable stratum extending from 100 feet to approximately 350 feet in which cracks, crevices, and caverns are numerous.

2. An impervious stratum between 350 and 650 feet.

3. A lower permeable stratum beginning at about 650 feet and extending to about 800 feet.

Figure 2 is a graphical representation of geological characteristics and water quality in the Floridan Aquifer as derived from data obtained during drilling and testing city well No. 4.

Piezometric Surface and Flow of Ground Water

Figure 3 shows the contours of the piezometric surface in the top part of the Florida Aquifer as of August, 1965, as well as pertinent points for future reference. These contours suggest that:

1. Ground water flows from a wide area around Gainesville to the city's well field which is located in the southeast section of the city.

2. East of Gainesville water flows from east-northeast to west toward Gainesville.

3. To the west and north ground water flows from southeast to northwest.

Very few wells in the Gainesville area penetrate both the upper and lower permeable strata and, as will be shown later, this fact is of paramount importance in interpreting and evaluating the results of this study.

Pollution of Aquifers

Evidence of Pollution - The source of water for the City of Gainesville is a group of seven wells located near the water treatment plant in the southeast section of the city. The four "old" wells, No's. 1-4, were initially drilled to depths of from 365 feet to 464 feet and penetrated only the upper aquifer. The three "new" wells, No's. 5-7, were drilled to depths of 713 feet to 750 feet and penetrate both the upper and lower aquifers. Well No. 1 has been abandoned and No's. 2 and 3 are rarely used.

Prior to 1960, wells No. 3, 4, 5, 6, and 7 produced water of good quality. However, about 1960, wells No. 4 and 6 began to show an increase in color and bacteriological count during periods of high rainfall. In November, 1963, the quality of water in wells No. 4 and 6 deteriorated rapidly, reaching a peak in January, 1964, after several days of abnormally high rainfall which had been preceded by several months of very dry weather. The presence of high organic color (150 units), high coliform counts (100+)

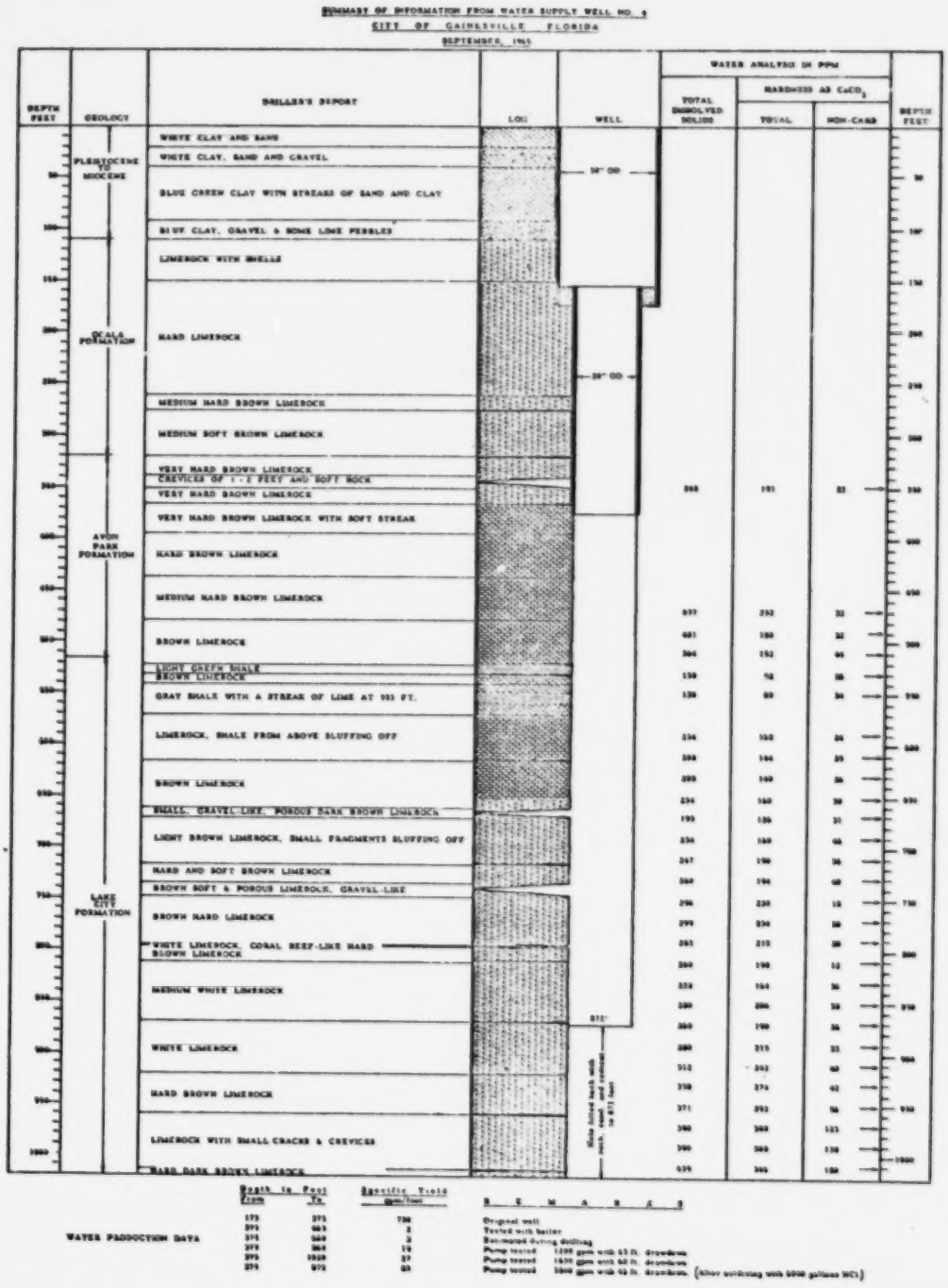


Fig. 2 - Summary of Information from Water Supply Well No. 4, City of Gainesville, Florida, September, 1965.

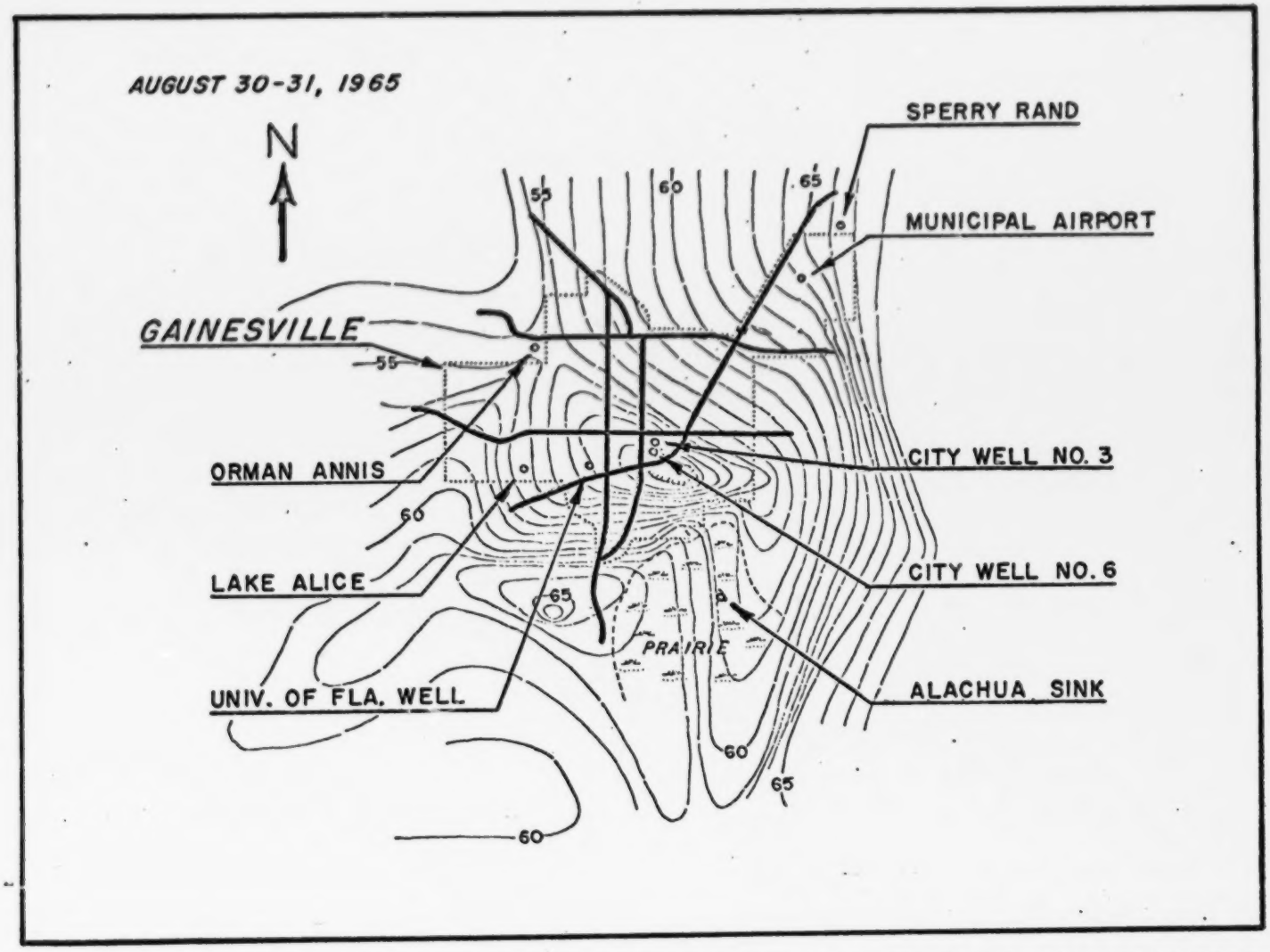


Fig. 3 - Contours of the Piezometric Surface in the Top Part of the Floridan Aquifer and Relative Location of Sample Points.

and a high concentration of detergents in well No. 6 suggested the presence of sewage pollution. A blanket of detergent foam several feet thick, produced by recarbonation of the treated water passing to the filters, is shown in Figure 4.

Corrective Measures - Polluted water was prevented from entering the two most highly polluted wells by relining well No. 6 to a depth of 331 feet and deepening well No. 4 to 872 feet and relining it to a depth of 375 feet. By so doing, the upper stratum from which the polluted water was entering the wells was cased out so that water pumped from these two wells is derived from only the lower permeable stratum.

Measurements made on well No. 6 over a three-year period include the random measurement of the piezometric level of water in both the upper and lower permeable strata. These data, which are tabulated in Table 1, show that the water level in the upper permeable stratum is higher than that in the lower stratum. These results indicate that there will be a downward flow of water from the upper to the lower stratum where connections between the two strata exist.

Table 1

Level of Water in the Upper and Lower Strata of the Floridan Aquifer, Well No. 6, City of Gainesville

	Depth from Surface to Water Level (feet)			
	Aug. 26, 1964	Oct. 29, 1964	Aug. 31, 1965	Apr. 25, 1967*
Lower stratum	87.9	85.1	86.2	86.4
Upper stratum	86.8	84.3	81.3	86.0
Difference	1.1	0.8	4.9	0.4

*Wells No. 5 and 7 were pumping when this measurement was made.

Possible Sources of Sewage Pollution - Two possible sources of sewage pollution existed on the periphery of the city: (1) the effluent from the University Sewage Treatment Plant, as well as wastes from the Teaching Hospital, which at that time emptied into a sinkhole on the University of Florida campus; and (2) effluent from the city's sewage treatment facility

Fig. 4 - Foaming at the Water Treatment Plant Due to Pollution of City Wells.

which eventually enters Alachua Sink via Sweet Water Branch. Both of these sinks are located approximately three miles from the city's well field, Alachua Sink to the south, and the sink on the University of Florida campus to the west.

On four occasions prior to 1964, the effluent of the University of Florida Sewage Treatment Plant had been traced through the sink on the University of Florida campus to the city well field. Tracers showed that water entering the sink reached the city's water treatment plant in less than ten hours, which means that the water traveled the straight line distance of approximately 9500 feet at a minimum velocity of 16 feet per minute.

After the evidence of sewage pollution in city well No. 6 in January, 1964, the University of Florida diverted the sewage effluent from the sink into Lake Alice and sealed off the sink. Lake Alice, however, is drained by two drainage wells located at the west end of the lake. Both of these drainage wells penetrate the upper permeable stratum of the Floridan Aquifer.

The University of Florida has three deep wells for use in connection with its steam and air conditioning plant. These wells are located immediately west of the Teaching Hospital and approximately 1.5 miles west of the city's wells. These wells penetrate the lower permeable stratum and are open to both the upper and lower strata. Tests conducted in the city's wells show that water is preferentially pumped from the upper stratum even though a well may penetrate both. These wells thus present a serious potential route for polluted water from the Lake Alice drainage wells to enter the lower stratum.

Selection of Sample Points

Sample points were selected to determine the source and extent of sewage pollution in the Floridan Aquifer near the City of Gainesville. The locations of sample points are given in Table 2 and represented graphically in Figure 5. Samples of water entering the ground at Alachua Sink and the drainage wells at Lake Alice were included to show the quality of water entering the ground at these points.

The wells which were selected are pumped frequently if not continuously and at a rate much greater than the usual home owner's well. These wells should serve as an excellent source of water representative of water in the aquifer in that particular area.

While it would have been desirable to sample each well used as a source of supply for the City of Gainesville, it was felt that initially typical wells could be used and other wells included as was deemed necessary. City well No. 3 was selected as a typical well extending only into the upper permeable stratum of the Floridan Aquifer, while well No. 6 was selected as a typical well extending into the lower stratum with the upper stratum cased out.

Table 2

Location and Pertinent Information Relative to Sample Points

Number	Name or Identification	Location	Total Depth (ft)	Casing		Pumping Rate or Flow (mgd)	Frequency of Pumping or Flow
				Depth (ft)	Diameter (in.)		
1	City well No. 3	605 SE 3d Street	421	170	18	2.9	As needed
2	City well No. 6	Approximately 800 SE 5th Street	750	331	24 - 20	4.0	Frequently
3	University of Florida	West of Teaching Hospital on Archer Road	909	183	24	2.5	Continuously
4	Ormon Annis properties	29th Place at NW 22d Street	330	175	6	0.3	As needed
5	Sperry Rand Corp.	Waldo Road	350	160	12	0.72	Continuously
6	Municipal Airport	Waldo Road	447	175	10	Unknown	Frequently
7	West drainage well at Lake Alice	Univ. of Florida Campus	235	83	24	4.2*	Continuously
8	Alachua Sink	Camp Ranch SE of 41st Avenue and 15th Street SE	---	---	---	40.0*	Continuously

*Average of three flow checks made by using an electric current meter manufactured by W. and L. E. Gurley Co., Troy, N. Y.

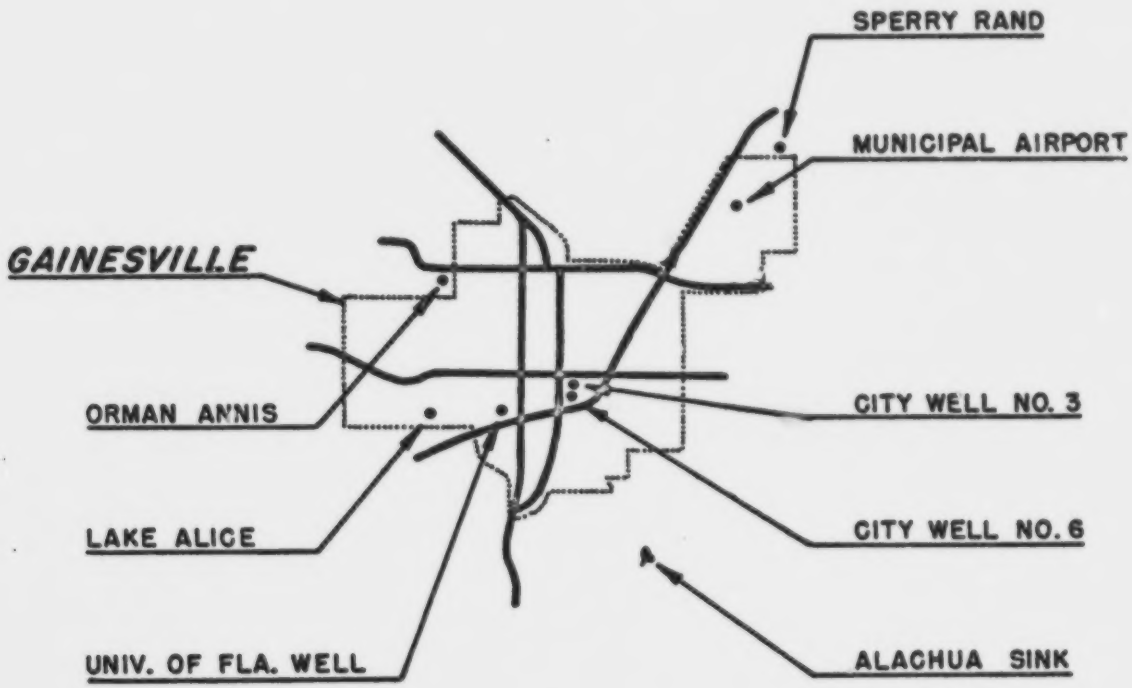


Fig. 5 - Relative Location of Sample Points.

The analyses to be made on samples collected from each sampling point were carefully selected to give meaningful information on water quality. At the beginning of the test period, 28 different determinations were made on each sample. However, a review of the data revealed that several of the determinations could be omitted without limiting the objectives of the study. The results which are summarized in Figure 5 were obtained from the analysis of water collected from each sample point from November, 1966, to September, 1967. The methods of analysis are given in Standard Methods for the Examination of Water and Waste Water.

Discussion of Results

Forms of Nitrogen - The concentrations of free ammonia, organic ammonia, and nitrate, all expressed as nitrogen, are shown in Figure 6. A measurable concentration of nitrite was found only twice, once at Alachua Sink and once at Orman Annis' well. High values for the three most prevalent forms of nitrogen were found in water from Lake Alice, Alachua Sink, and well No. 3, with relatively high values for free ammonia in well No. 6.

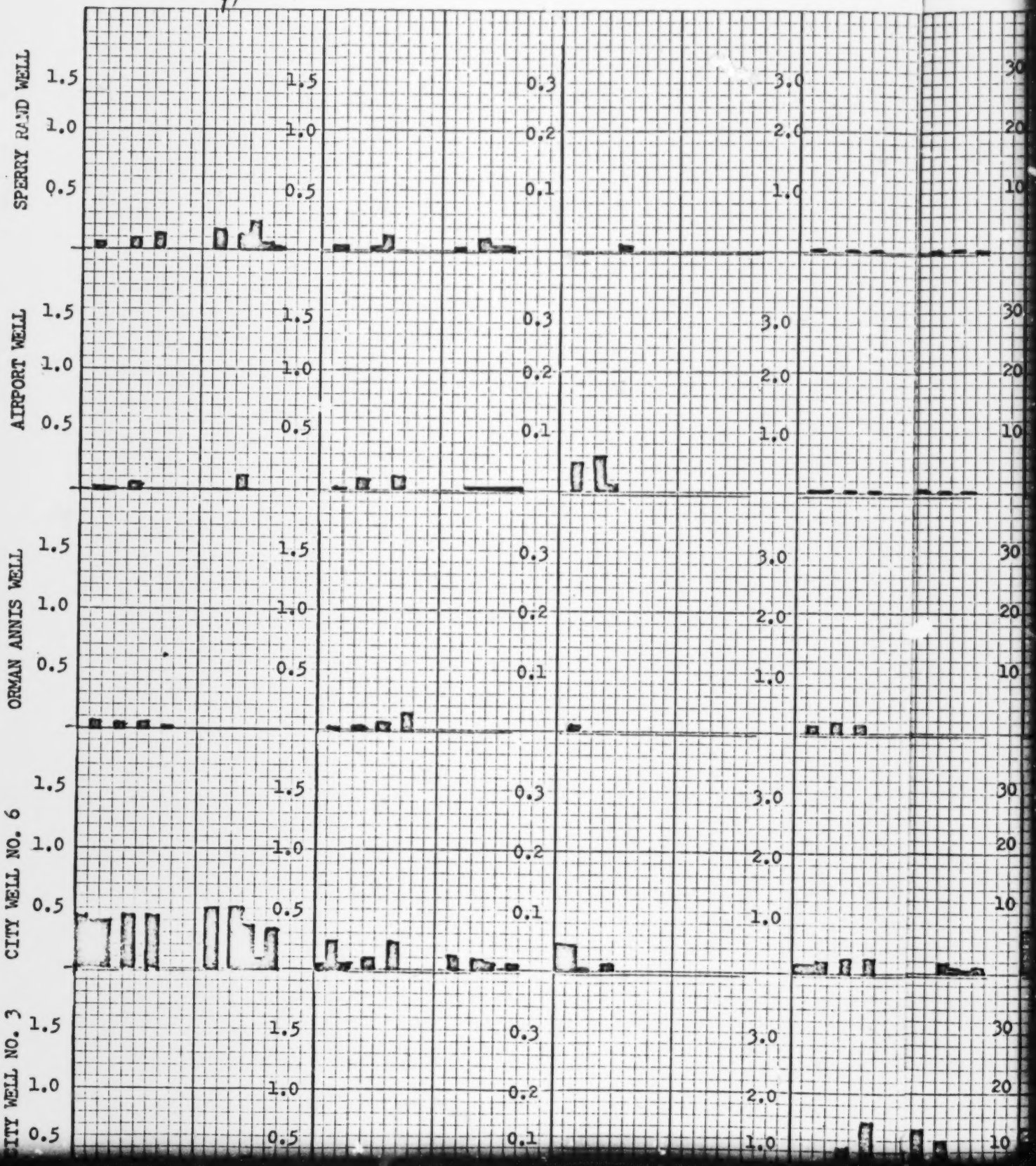
The presence of organic ammonia, free ammonia, and nitrate-N in the concentrations found indicate that nitrogenous organic matter and its products of decomposition are present in waters to the west and south of the present well field. The absence of nitrite-N and the presence of nitrate-N suggest that the process of decomposition is stabilized and that the pollutants are not of recent origin.

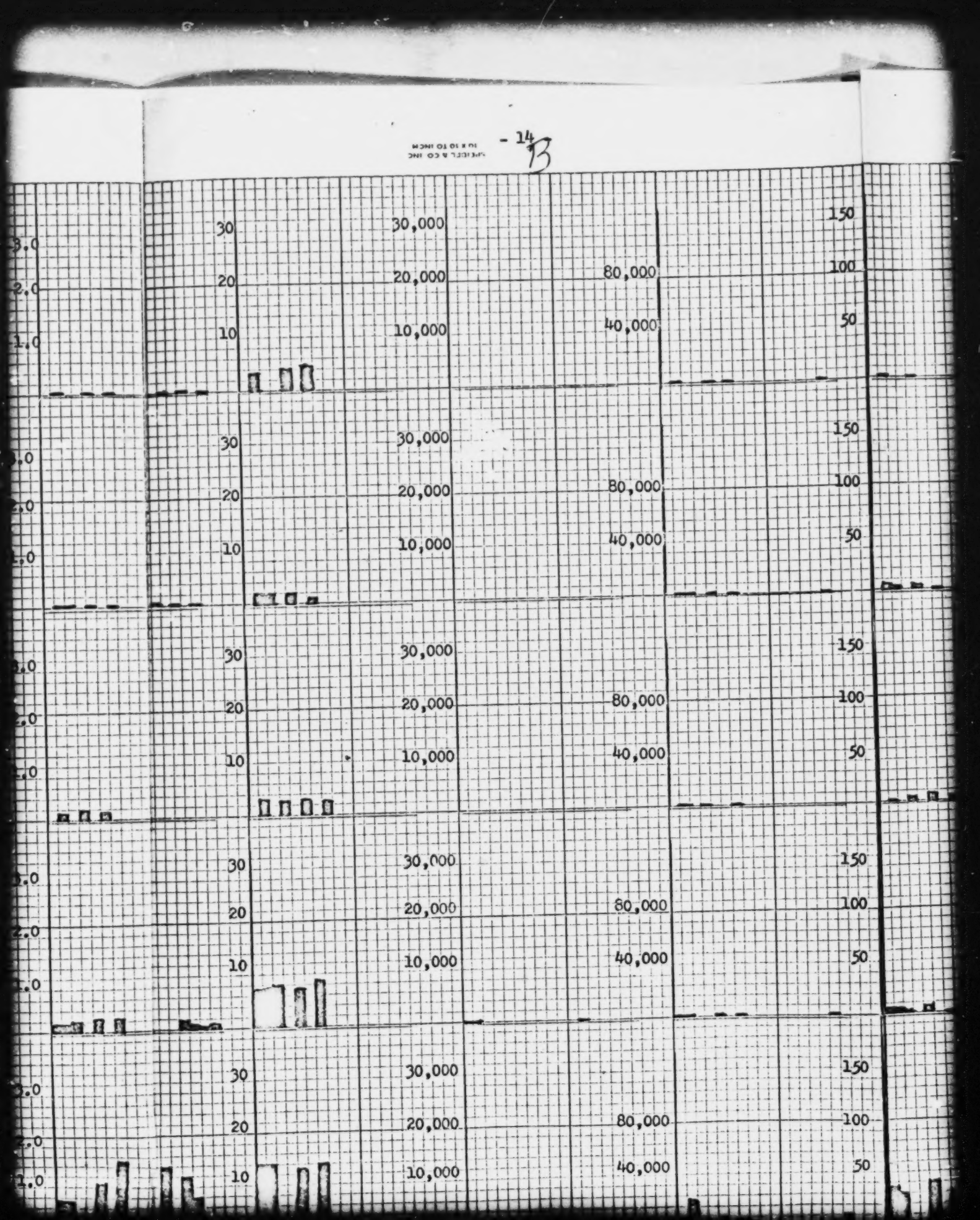
Low values for all forms of nitrogen were found in waters from sample points northeast of the city. This was to be expected since the piezometric level of water in this area is higher than that found in other areas in Gainesville.

Phosphate - Both total phosphate and orthophosphate determinations were made on most of the samples collected during this study. The results showed that orthophosphate was essentially equal to total phosphate, indicating that if polyphosphates were present their concentration was very low. As may be seen in Figure 6, high concentrations were found in Lake Alice, Alachua Sink, and well No. 3, with lower values in well No. 6 and the University of Florida well.

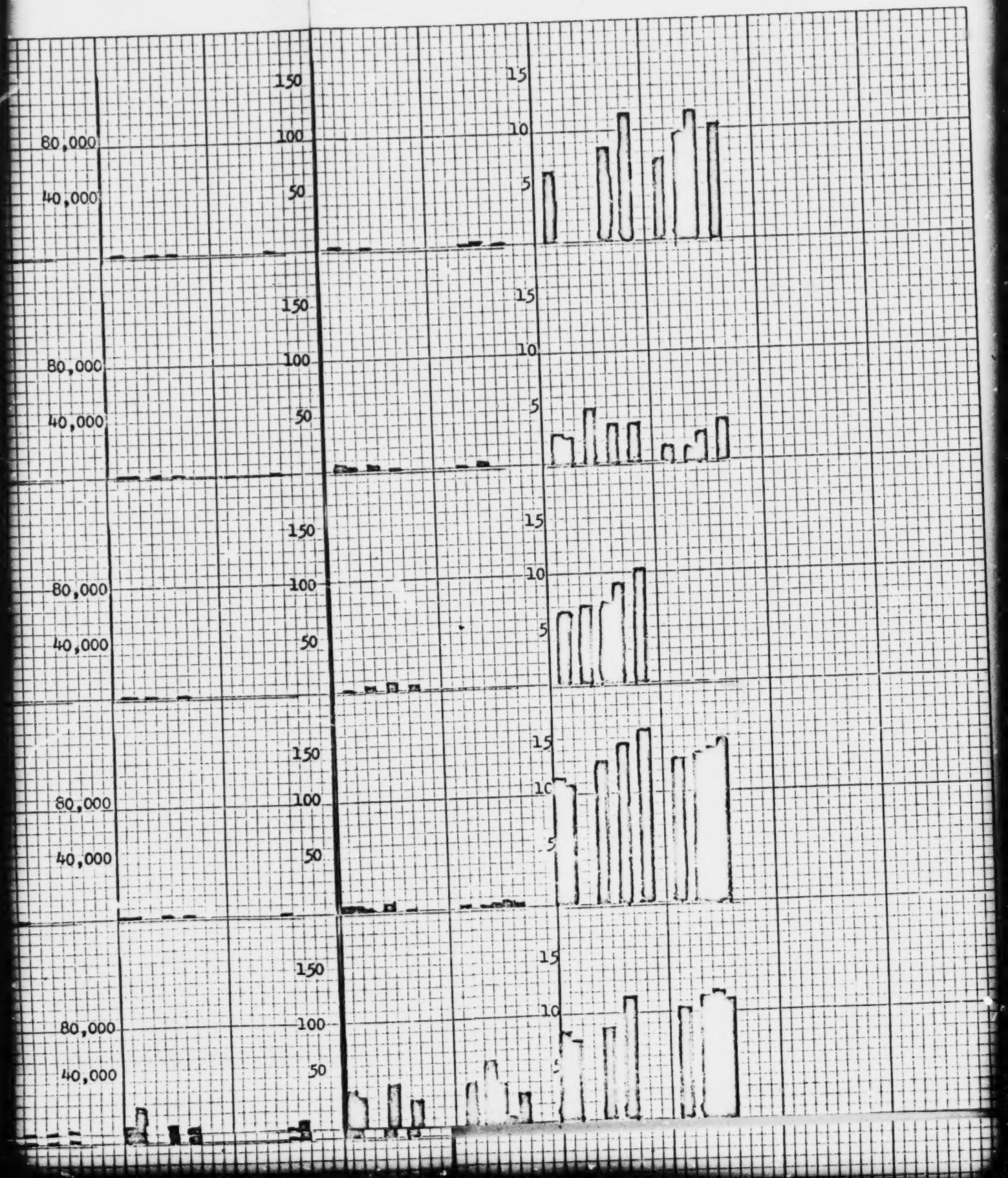
Chlorine Demand - For the purpose of this study, chlorine demand is defined as the initial concentration of chlorine which is necessary to give a one ppm free residual at the end of 24 hours. Samples containing hydrogen sulfide were aerated for one hour and then allowed to stand until no hydrogen sulfide was present prior to setting up the demand study.

The chlorine demand from most sampling points remained quite uniform during the sampling period except for Alachua Sink and Lake Alice where, as would be expected, substantial variations were noted. Data which are presented in Figure 6 show that the higher demands were found in water from Lake Alice, Alachua Sink, and well No. 3 with a lower demand in well No. 6. Minimum values of from 2-4 ppm were obtained at all other points.


A
SPERRY RAND WELL
AIRPORT WELL
ORMAN ANNIS WELL
CITY WELL NO. 6
CITY WELL NO. 3
1.5
1.0
0.5
0.3
0.2
0.1
3.0
2.0
1.0
30
20
10


30
20
10
30,000
20,000
10,000
80,000
40,000
150
100
50

c



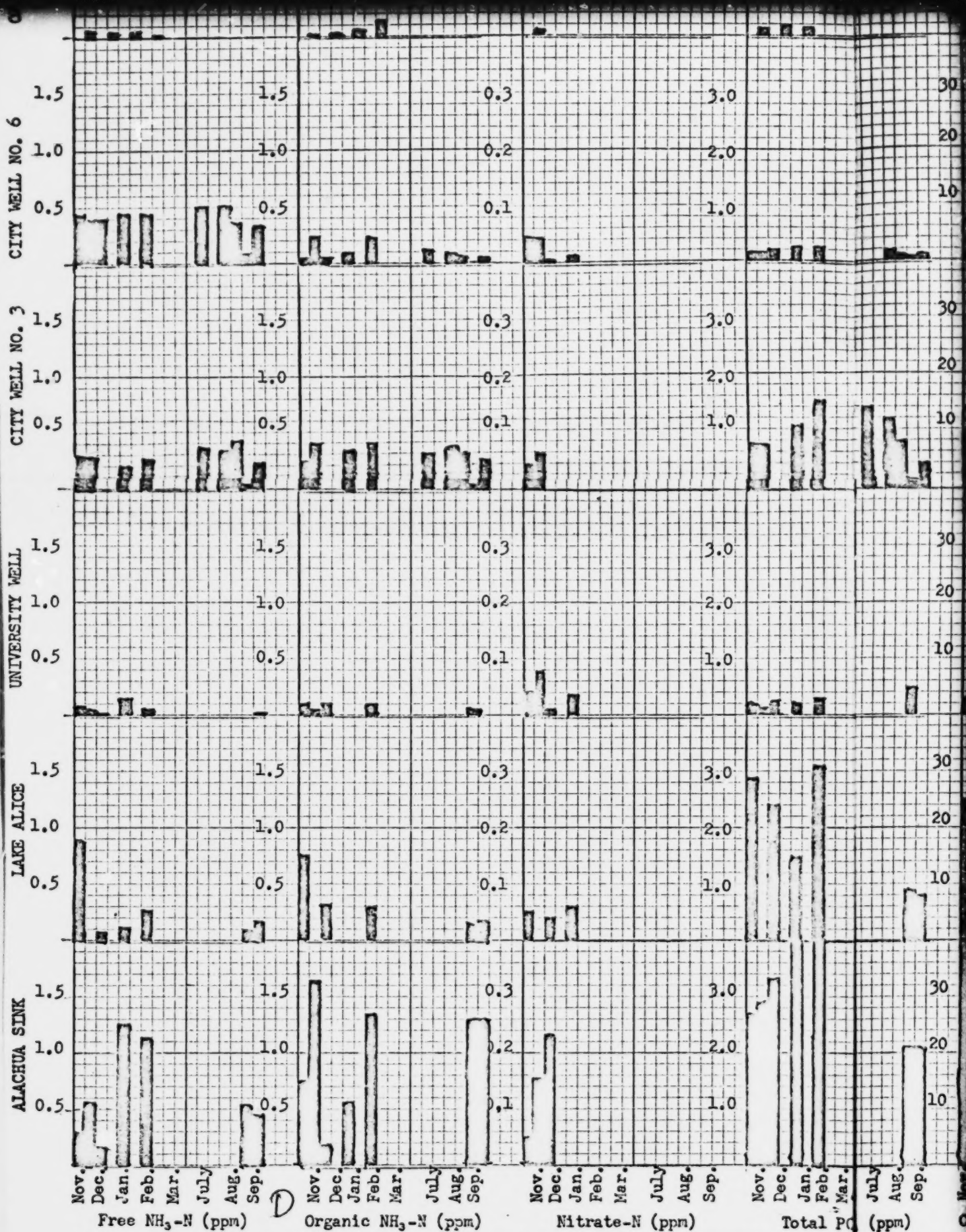
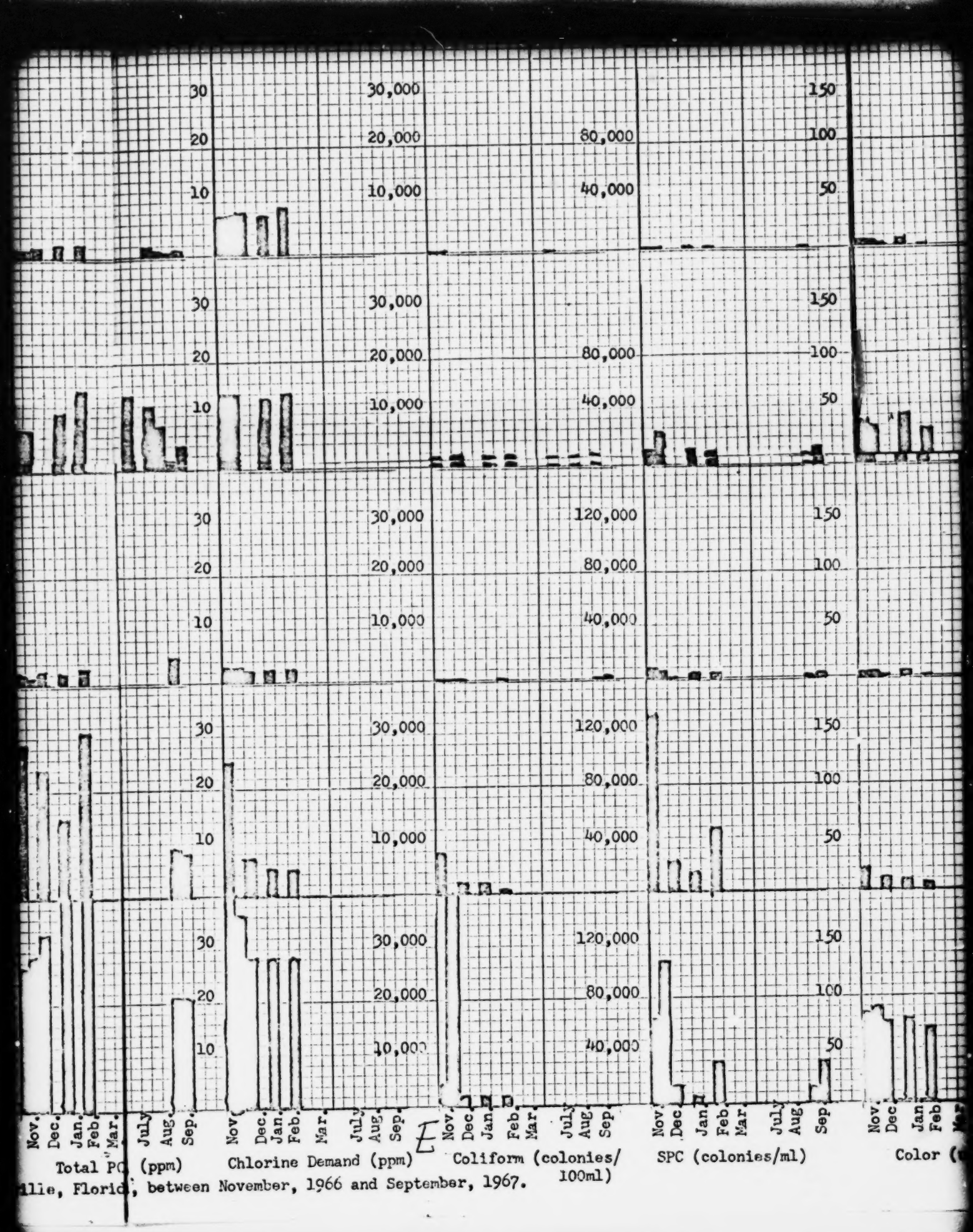
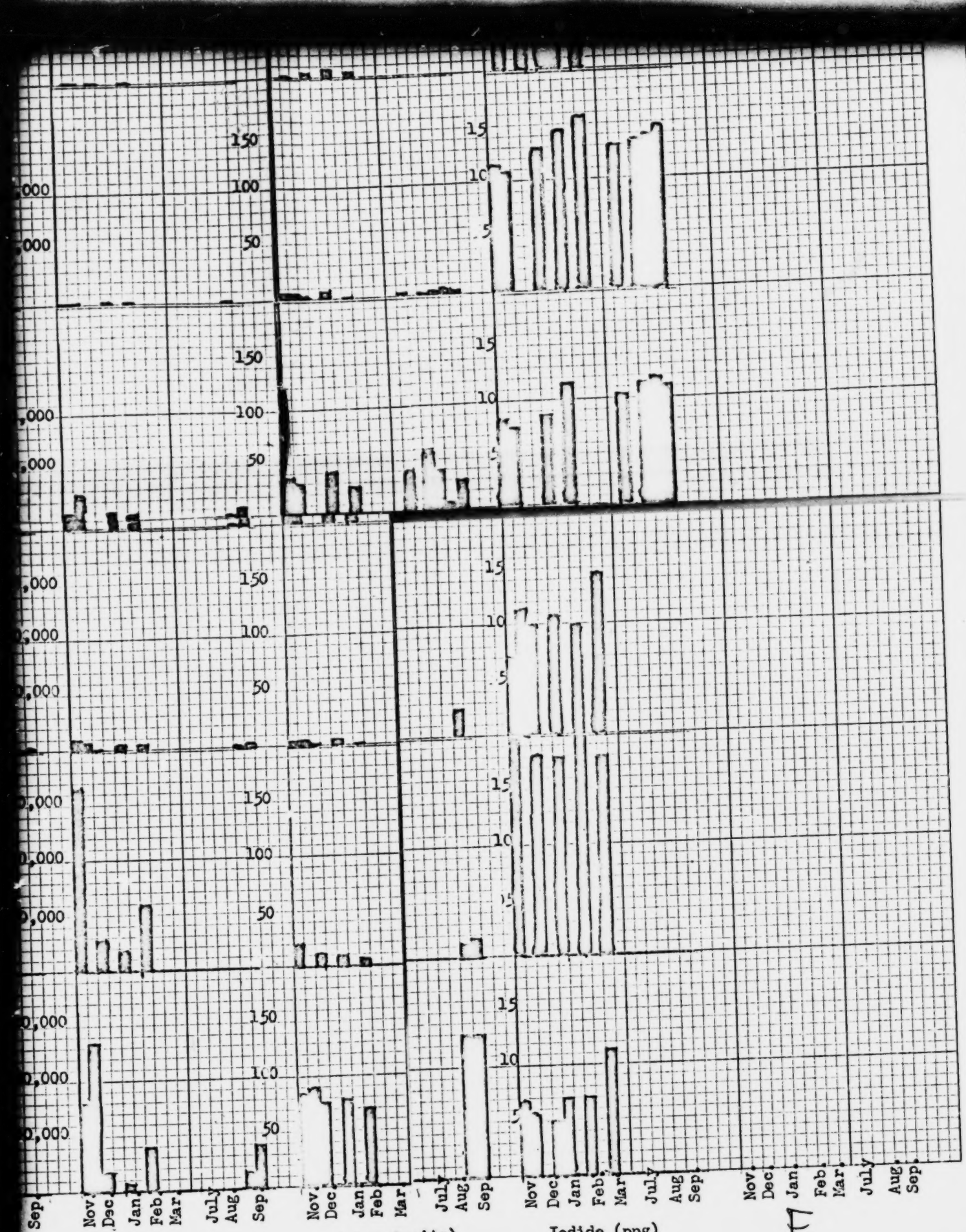


Fig. 6 - Comparison of Water Quality From Several Sources Around Gainesville, Florida, between No



Total P[illegible] (ppm) Chlorine Demand (ppm) Coliform (colonies/100ml) SPC (colonies/ml) Color ([illegible]

[illegible]lle, Florid[illegible], between November, 1966 and September, 1967.


150
100
50
15
10
5
Nov.
Dec.
Jan.
Feb.
Mar.
July
Aug.
Sep.
SPC (colonies/ml)
Color (units)
Iodide (ppg)

The chlorine demand of these waters suggest that higher concentrations of organic matter are present in ground water to the west and south of the present well field than in other areas around the city. The low values obtained for sample points northeast of the city indicate that organics, if present occur in low concentrations in this area.

Bacteriology - The values for both coliforms and standard plate count show that large numbers of organisms are present in water from Lake Alice and Alachua Sink. These data constitute further evidence that pollutants of fecal origin are present in both Lake Alice and Alachua Sink and that these polluted waters are finding their way into wells on the University of Florida campus and into the city's well field.

Color - While the presence of organic color in a water is not necessarily an indication of sewage pollution, it serves as an excellent tracer for determining the route which water takes in traveling from one location to another.

Data from Figure 6 show the intensity of color found at each of the sampl points. The color of the water at Lake Alice is less than that in well No. 3, while water from Alachua Sink is significantly higher in organic color than well No. 3. These data suggest that Alachua Sink is the prime source of the organic color which is found in the city wells penetrating the upper permeable stratum of the Floridan Aquifer.

Iodide - Figure 6 shows the results of several determinations of iodide in water from the seven sampling points between November 1966 and September 1967, and Table 3(b) gives average values for each water, together with average values for water from three city wells not otherwise used as sampling points. Table 3(a) gives the iodide content of the water from Silver Springs, Florida, and from 440 foot and 1083 foot wells in the Ocala area, about 40 miles south of Gainesville, and all of which is derived from the Floridan Aquifer.

The relatively high values found for water from the drainage well at Lake Alice are believed to be due to the fact that it receives the filter wash water from the 500,000 gallon swimming pool of the University of Florida, which has been disinfected with iodine for the past four years. The filter wash water may contain as much as 1500 ppb of iodide ion. There is no indication from the limited amount of data accumulated to date to indicate that its presence in these drainage wells has had any significant effect upon the concentration of iodide found in the other wells. About all the data appear to show is that the amount of iodide present in water from wells in both the study area and the Ocala area is somewhat less in the shallower wells than in the deeper ones. The very low value of 2.8 ppb for water from the airport well is cause for some concern. The iodide content of most of the other wells studied is less than 50% of the 20 ppb of iodide which most endocrinologists consider about the optimum amount for drinking water. This well, containing only 14% of that recommended amount, is located less than one mile from the area within which the new wells for the city will be drilled.

Table 3 (a)

Characteristics of Three Sources of Water in the Ocala Area

	Silver Springs	City of Ocala Well No. 3	Libby McNeil and Libby Well No. 3
Total depth (ft)	?	440	1083
Casing diameter (in)	---	20	26
Depth of casing (ft)	---	259	850
Pump yield (mgd)	---	4.0	7.5
Iodide, as I (ppb)	9.0	7.6	16.9

Recurrence of Gross Pollution in City Wells

Evidence of Pollution - During July 1967, after a period of intense rainfall which had been preceded by a period of very dry weather, Figure 7, the quality of water in city wells No. 3, 5, and 7 deteriorated rapidly. The presence of high organic color, high coliform counts, and high concentrations of phosphate suggested that pollutants of sewage origin were again finding their way into the upper permeable stratum of the Floridan Aquifer and into the city's well field.

Sampling Program - An intensive sampling program was initiated to follow this change in water quality with particular emphasis on water from the city's wells. Data from each of the city's wells are summarized in Figure 8. The three wells which are open to the upper permeable stratum (wells No. 3, 5, and 7) show evidence of gross pollution, while those which penetrate the lower permeable stratum with the upper stratum cased out continued to yield water of good quality. It is also of interest to note that the concentration of pollutants decreased during August and September as the rainfall returned to a more normal pattern.

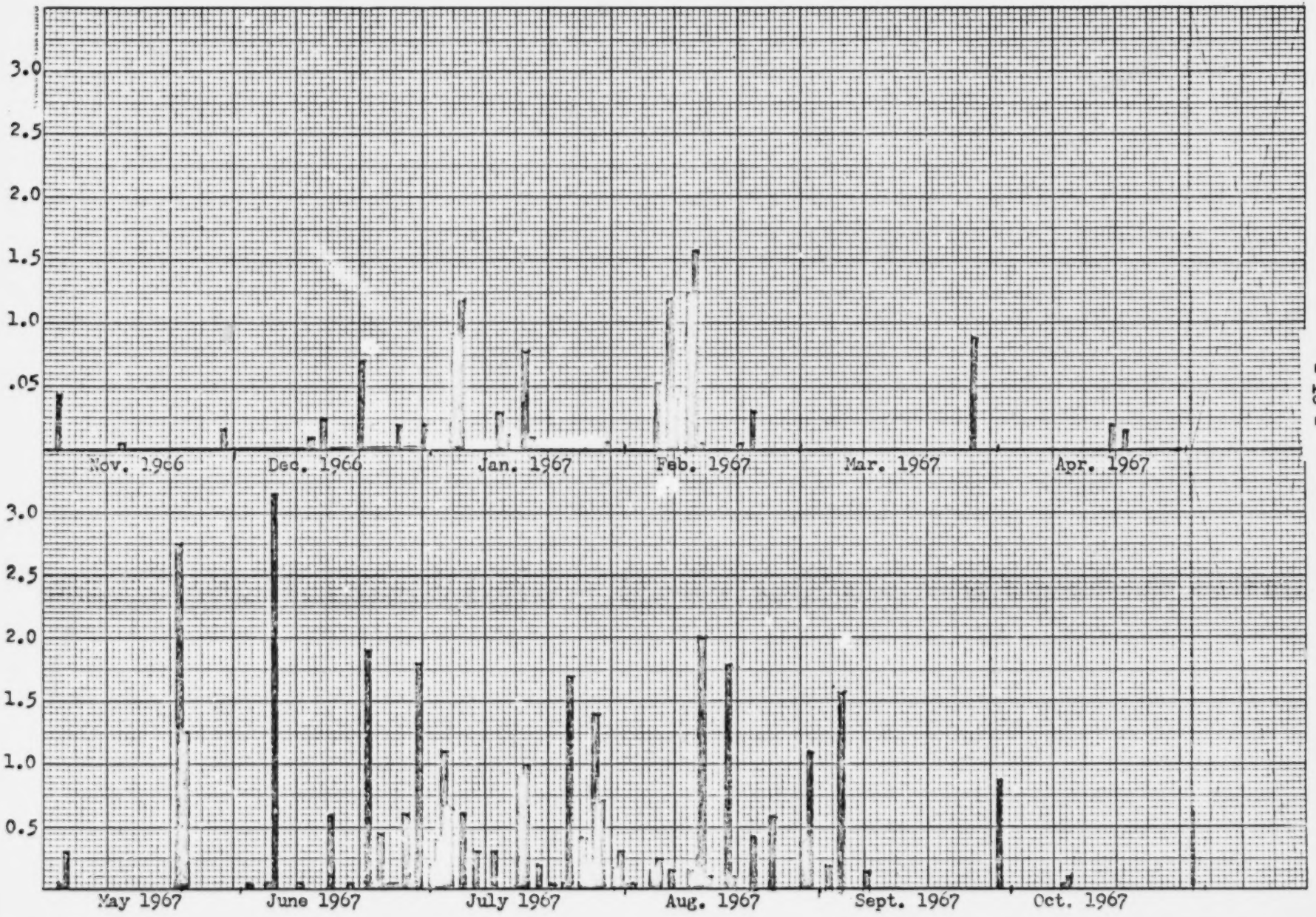
The deterioration in water quality following a period of intense rainfall which had been preceded by several months of dry weather followed the same pattern as that first observed in 1963-64.

Table 3 (b)

Concentration of Iodide Ion in Study Sources

Study Source	Depth	Iodide Ion, ppb
City Well No. 3	421	10.1
City Well No. 4	872	9.2
City Well No. 5	742	9.9
City Well No. 6	750	13.4
City Well No. 7	713	12.2
University of Florida Well	909	10.6
Drainage Well at Lake Alice	235	18.8
Ormon Annis Well	330	8.0
Sperry Rand Well	350	9.3
Municipal Airport Well	447	2.8
Alachua Sink	---	7.2
* * * * * * * * *		
Average for 3 wells, 330', 350', and 421' deep		9.1
Well at Municipal Airport, 447' deep		2.8
Average of four wells 872', 742, 750', and 713' deep		11.2

Fig. 7 - Rainfall During the Period of Investigation.



A

75
50
25
Color (units)
1.5
1.0
0.5
Phosphate (ppm PO4)
75
50
25
Coliform, colonies/100ml
15
10
5
COD (ppm)
.75
(ppm)

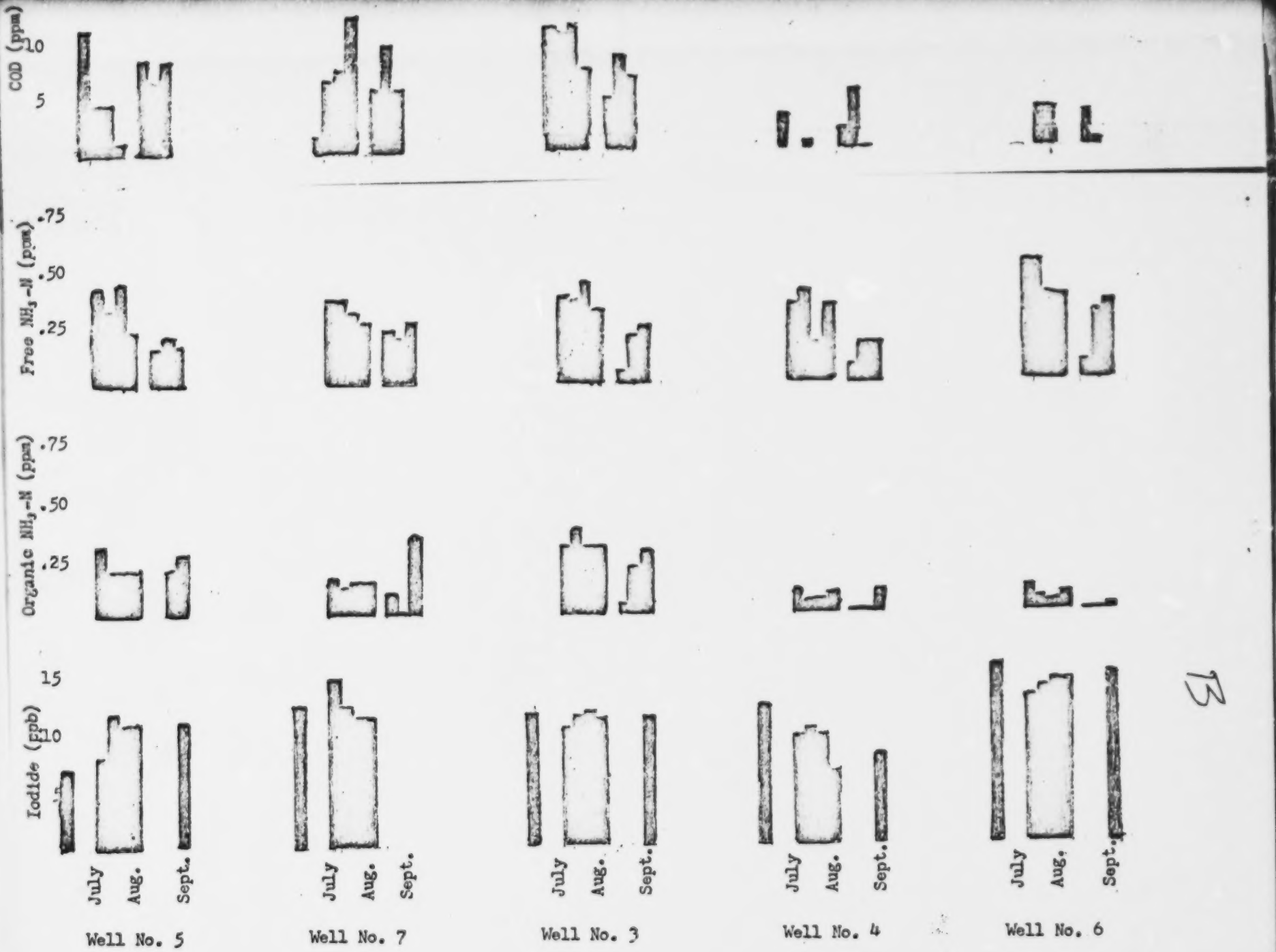


Fig. 3 - Comparison of Water Quality in Wells No. 3, 4, 5, 6, and 7, July - September, 1967.

Change in the Bacterial Quality of Water from the Well to the Consumer

Present Method of Treatment - The water treatment plant is designed for lime-soda softening of the water. The raw water enters an upflow solids contact unit where return sludge, activated silica, and lime slurry are added. The softened and clarified water passes through a recarbonation basin where the pH is reduced from about 10.3 to its stabilization pH of about 8.6 prior to being filtered through rapid and gravity filters.

Disinfection practice consists of the addition of from 9 to 12 ppm of chlorine to the water entering the upflow solids contact unit. A free chlorine residual is maintained through most of the plant, with ammonium sulfate added as the water leaves the softening unit to provide a chloramine residual of at least 2 ppm leaving the treatment plant.

Bacteriological Quality of Water - In order to evaluate the effectiveness of water treatment, a study was made to determine the change in bacteriological quality of the water as it passed through the water treatment plant and distribution system.

Samples of the water were taken at preselected points in the treatment plant for pH, chlorine residual, and bacteriological determinations. On each occasion water was being pumped from wells No. 5 and No. 7 at a combined rate of 10 mgd with 10.5 ppm of chlorine added to the Accelator. The location of each sample point is given in Table 4.

For bacteriological determinations, the first six sets of samples were collected in sterile bottles containing sodium thiosulfate. The seventh set was collected in sterile bottles containing no sodium thiosulfate so that the effect, if any, of additional contact time with chlorine could be observed. All samples for bacteriological determinations were taken in triplicate.

The data given in Tables 5 through 9 indicate that confirmed coliforms and coliforms capable of producing gas at 44.5°C on brilliant green bile lactose broth were present in the influent to the water plant on several occasions. The samples taken between September 11 and 13, 1967, showed fecal coliforms to be present in 4 of 17 samples. This shows that the water entering the plant was definitely of poor bacteriological quality. No coliform organisms were found in the Accelator effluent even though the pH was maintained between pH 10.2 and 10.3. A free chlorine residual of between 1.7 and 2.0 was always present.

Standard plate counts were reduced to between 6 and 20 bacteria per ml in water leaving the Accelator even though counts in the raw water ranged between 120 and 970 per ml.

Chlorine residuals determined by amperometric titration show that a free chlorine residual was maintained through the plant. While ammonium sulfate is added to the water between the Accelator and the recarbonation basin (between sample points 2 and 3), a few minutes are required to complete the reaction between free chlorine and the ammonium ion added.

Table 4

Location of Sample Points in the Water Treatment Plant

Sample Number	Location
1	Influent from wells
2	Accelator effluent
3	In flume immediately upstream of the recarbonation basin
4	In flume entering the rapid sand filters after recarbonation
5	Filter effluent
6	Tap in laboratory at water treatment plant
7	Effluent from sand filters collected in bottles which contained no sodium thiosulfate

In evaluating these data on the basis of chlorine residual, it must be remembered that even though a free chlorine residual was present, less than ten percent was present as hypochlorous acid, and more than 90 percent was present as hypochlorite ion, due to the high pH of the water. In all but one instance, Table 7, chloramines accounted for at least one-half of the total chlorine present in the water leaving the Accelator. Both chloramines and the hypochlorite ion are known to be relatively ineffective as disinfectants.

Data published by Riehl, Weise, and Rheims and others show that E. coli and other bacteria are killed by exposure to water of high pH for a period of time which depends on the pH of the water. A pH value of 11.0 or more is necessary, however, for disinfection within the retention time provided in most plants.

The bacteriological quality of water taken from four widely spaced points in the distribution system was determined once each week from November 8, 1966 through April 4, 1967. Please see Table 10.

The length of time required for water to travel from the water treatment plant to point No. 1 was determined to be approximately three hours, points

Table 5

Changes in Bacteriological Quality, pH and Chlorine Residual as Water Passes Through the Water Treatment Plant, 3 to 5 AM, Nov. 29, 1966

Sample No.	Coliform Membrane Filter	Coliform MPN/100 cc 35°C	Coliform MPN/100 cc 44.5°C	48-hour plate Count. Bacteria/ml	pH	Amperometric Free Cl_2	Amperometric Comb. Cl_2	Amperometric Total Cl_2	Contact Time (min) (calculated)	Sample Time (AM)
1	18	7.0	2.0	837	7.20	0	0	0	0	4:10
2	< 1	< 2.0	< 2.0	13	10.2	1.71	1.85	3.56	57.5	3:42
3	< 1	< 2.2	< 2.2	10	10.2	0.73	2.79	3.52	58.3	4:20
4	< 1	< 2.2	< 2.2	8	8.75	0.70	2.44	3.14	60.1	4:30
5	< 1	< 2.2	< 2.2	7	8.70	0.18	2.62	2.80	64.1	4:50
6	< 1	< 2.2	< 2.2	4	8.90	0.01	2.06	2.07	--	5:10

*Average of three values

Table 6

Changes in Bacteriological Quality, pH and Chlorine Residual as Water Passes Through the Water Treatment Plant, 5 to 6 AM, Nov. 29, 1966

Sample No.	Coliform Membrane Filter*	Coliform MPN/100 cc 35°C	Coliform MPN/100 cc 44.5°C	48-Hour Plate Count* Bacteria/ml	pH	Amperometric Free Cl_2	Amperometric Comb. Cl_2	Amperometric Total Cl_2	Contact Time (min) (calculated)	Sample Time (AM)
1	68	7.0	< 2.0	970	7.25	0	0	0	0	5:30
2	< 1	< 2.0	< 2.0	9	10.30	2.02	2.10	4.12	57.5	5:35
3	< 1	< 2.2	< 2.2	7	10.20	0.90	2.99	3.89	58.3	5:42
4	< 1	< 2.2	< 2.2	8	8.40	0.80	2.86	3.66	60.1	5:48
5	< 1	< 2.2	< 2.2	6	8.45	0.15	2.49	2.64	64.1	6:02
6	< 1	< 2.2	---	6	8.70	0.02	2.09	2.11	---	6:10
7	< 1	< 2.2	< 2.2	7	8.70	0.02	2.09	2.11	314	6:15

*Average of three values

Table 7

Changes in Bacteriological Quality, pH and Chlorine Residual as Water Passes Through the Water Treatment Plant, 3 to 4 AM, Dec. 20, 1960

Sample No.	Coliform			48-Hour Plate Count*		Amperometric			Contact Time (min)	Sample Time
	Membrane Filter*	MPN/100 cc 35°C	MPN/100 cc 44.5°C	Bacteria/ml.	pH	Free Cl_2	Comb. Cl_2	Total Cl_2	(calculated)	(AM)
1	9	2.0	--	410	7.39	0	0	0	0	3:12
2	< 1	< 2.0	< 2.0	13	10.12	2.08	1.51	3.59	57.5	3:22
3	< 1	< 2.2	< 2.2	14	10.26	1.71	2.44	4.15	58.3	3:35
4	< 1	< 2.2	< 2.2	12	7.80	1.30	1.00	2.30	60.1	3:53
5	< 1	< 2.2	< 2.2	9	7.81	0.88	0.57	1.45	64.1	4:00
6	< 1	< 2.2	< 2.2	4	8.47	0.28	1.36	1.64	---	4:12

*Average of three values

Table 8

Changes in Bacteriological Quality, pH and Chlorine Residual as Water Passes Through the Water Treatment Plant, 4 to 5 AM, Dec. 20, 1966

Sample No.	Coliform Membrane Filter*	Coliform MPN/100cc 35°C	Coliform MPN/100cc 44.5°C	48-Hour Plate Count* Bacteria/ml	pH	Amperometric Free Cl_2	Amperometric Comb. Cl_2	Amperometric Total Cl_2	Contact Time (min) (calculated)	Sample Time (AM)
1	9	16	< 2.2	180	7.45	0	0	0	0	4:24
2	< 1	< 2.2	< 2.2	17	10.19	2.00	2.07	4.07	57.5	4:26
3	< 1	< 2.2	< 2.2	11	10.32	1.52	3.00	4.52	53.3	4:30
4	< 1	< 2.2	< 2.2	9	7.89	0.74	2.22	2.96	60.1	4:50
5	< 1	< 2.2	< 2.2	10	8.01	0.52	1.06	1.58	64.1	4:55
6	< 1	< 2.2	< 2.2	8	8.42	0.22	1.30	1.52	---	5:10
7	< 1	--	--	8	8.11	0.32	1.30	1.62	379.0	5:15

*Average of three values

Table 9

Changes in Bacteriological Quality as Water Passes Through the Water Treatment Plant, September 11 - 21, 1967

	Sample Points				
	1			2	
Date	Confirmed[1] Coliform MPN/100cc	Fecal[2] Coliform MPN/100cc	48-Hour Plate Count Bacteria/ml	Confirmed Coliform MPN/100cc	48-Hour Plate Count Bacteria/ml
1967					
Sept. 11	< 20.0	<20.0	460	< 2.0	6
Sept. 12	23.0	8.0	390	< 2.0	8
Sept. 13	13.0	< 2.0	520	< 2.0	10
Sept. 14	17.0	4.0	480	< 2.0	6
Sept. 19	33.0	< 2.0	120	---	---
Sept. 20	49.0	2.0	280	---	---
Sept. 21	23.0	13.0	640	---	---

[1]Brilliant green lactose bile broth.

[2]EC medium.

*Too numerous to count.

Table 9 - Extended

Sample Points				
3		Clear Well Effluent		
Confirmed Coliform MPN/100cc	48-Hour Plate Count Bacteria/ml	Lactose Fermentation	Confirmed Coliform MPN/100cc	48-Hour Plate Count Bacteria/ml
< 2.0	5	+	23.0	THC*
< 2.0	8	+	< 2.0	1030
< 2.0	7	+	< 2.0	1200
< 2.0	15	-	---	---
---	---	+	< 2.0	5
---	---	+	< 2.0	10
---	---	+	< 2.0	5

Table 10

Coliform and Standard Plate Count at Four Sampling Points in the Distribution System

Sample Point	No. 1		No. 2	
Date	Coliform Colonies Per 100cc	48-Hour Plate Count Bacteria/ml	Coliform Colonies Per 100cc	48-Hour Plate Count Bacteria/ml
Nov. 8, 1966	< 1	4	< 1	5
Nov. 29, 1966	< 1	2	< 1	4
Dec. 13, 1966	< 1	3	< 1	4
Dec. 20, 1966	< 1	2	< 1	1
Dec. 28, 1966	< 1	3	< 1	8
Jan. 10, 1967	< 1	3	< 1	3
Jan. 17, 1967	< 1	2	< 1	3
Jan. 25, 1967	< 1	3	< 1	3
Feb. 7, 1967	< 1	1	< 1	4
Feb. 14, 1967	< 1	3	< 1	11
Feb. 28, 1967	< 1	1	< 1	1
Mar. 7, 1967	< 1	1	< 1	1
Mar. 14, 1967	< 1	2	< 1	1
Mar. 22, 1967	< 1	1	< 1	1
Mar. 28, 1967	< 1	1	< 1	1
Apr. 4, 1967	< 1	3	< 1	2

Table 10 - Extended

No. 3		No. 4	
Coliform Colonies Per 100cc	48-Hour Plate Count Bacteria/ml	Coliform Colonies Per 100cc	48-Hour Plate Count Bacteria/ml
< 1	1	< 1	3
< 1	4	< 1	3
< 1	3	< 1	2
< 1	1	< 1	4
< 1	160	< 1	> 1000
< 1	4	< 1	6
< 1	1	< 1	1
< 1	3	< 1	3
< 1	3	< 1	< 1
< 1	4	< 1	2
< 1	1	< 1	1
< 1	3	< 1	2
< 1	1	-	-
< 1	2	< 1	1
< 1	1	< 1	1
< 1	2	< 1	1

No. 2 and No. 3, 12 hours, and point No. 4, 27 hours. These data, together with those provided by the city's routine testing program, demonstrated that a water meeting the standards of bacterial quality as set by the 1962 DRINKING WATER STANDARDS is being continuously produced from raw water of questionable purity.

B. Industrial Pollution of Ground Water in the Study Area

A major chemical company has for several years operated a manufacturing plant on the northeastern perimeter of the city. Pine stumps were retorted, the main products being pine tar and charcoal briquets. The waste is a dark brown to black viscous liquid containing pyroligneous acid, higher alcohols and phenols. Disposal has been by ponding in a series of shallow lagoons on the plant property. During periods of high rainfall, run-off water from the ponds finds its way through small channels to a drainage ditch and ultimately into one of the headwater streams of Hogtown Creek, which flows through the west and southwest sections of the city, and finally discharges into Kanapaha Sink, which is located in Sugarloaf Prairie, a total flow distance of about eight miles.

In 1965, Sundaresan et. al., studied the effects of this waste on the microbial ecology of Hogtown Creek. During the period of their study the amount of waste entering the headwaters of the stream was about 20 gpm, and the measured total flow approximately five miles downstream was about 400 gpm. A partial chemical analysis of the waste entering the creek was shown by them as follows:

Table 11

Partial Chemical Analysis of Wood Reduction Waste Entering Hogtown Creek

Characteristic	Value
pH	6.8
DO	0 mg/l
BOD	930 mg/l
COD	4,200 mg/l
Nitrogen (Ammonia)	Nil
Nitrogen (Organic)	450 mg/l
Phenol	2.0 mg/l

They found, as would be expected from the composition of the waste, that it adversely affected the biota of the stream.

Shortly after the study was made and published, the company phased out the operation, dismantled the plant and sold the plant site, including the waste-filled lagoons, to a local contractor. On October 26, 1967, the concentrated waste from the lagoons, containing a large amount of highly viscous, tarry material was discharged into Hogtown Creek by way of the drainage ditch for a period of several hours, passing downstream for a total distance of about two miles. The incident resulted in a large amount of publicity, resulting in court action against the polluter, and several civil suits have been instituted for damages by owners of property along the creek.

In our efforts to pinpoint specific sources of ground water pollution in the study area, numerous dye tracer studies have been made, but the results have been inconclusive since the aromatic polyhydroxy carboxylic acids which constitute at least a portion of the organic color present in water from most of the wells fluoresce brilliantly in ultraviolet light, making it impossible to differentiate them from the tracer dyes used. Accordingly, at the time this incident took place, we were searching for some type of indicator material which could be added at known points of entrance of sewage pollution into the ground water strata. The presence of "phenols" in the pollution material appeared to provide such an indicator. Accordingly, the necessary laboratory equipment and chemicals were immediately obtained, all swimming pool work temporarily discontinued, and all available personnel used for a phenol monitoring program which included the determination of "phenols," initially twice per week and later once per week, in samples collected from 18 sampling points throughout the study area. In addition, a new part-time research assistant was added to initiate a program of separating and identifying these materials by gas chromatography. A second and even more important objective of this new approach is separation and identifying, if possible, the odor-producing compounds resulting from the addition of both chlorine and iodine to the municipal water supply and to water from individual wells.

Determination of "Phenols" in Water and Industrial Waste

The methods being used for the determination of these phenolic compounds are those given in the Twelfth Edition of Standard Methods for the Examination of Water and Waste Water. These methods leave much to be desired. Three methods are given, all based upon the fact that many substituted phenols react to form a colored complex with a mixture of 4 amino antipyrine and potassium ferricyanide. In the first two methods, the phenolic materials are separated from the sample which has been treated with $CuSO_4$ and H_3PO_4 by distillation, and the determination made on the distillate. The most accurate procedure is to buffer a measured volume of the distillate to pH 10 $\pm$ 0.2, add the two reagents, allow to stand for 3 minutes and then extract the colored compound with chloroform, measure the absorbance at about 460 mμ and estimate the phenol concentration from a standard curve obtained by carrying solutions of known phenol concentration through the same procedure. A simpler but less sensitive method consists in buffering a measured volume of distillate

Head of Dark Gray Foam (Arrow) Sits on Water at 34th Street Spillway.

Hogtown Creek Fit for Hogs Only

By NORM LaCOE, Sun Staff Writer.. ....

Hogtown Creek is a sick stream these days, covered with foam at one end, sliding along on a bed of black ooze at the other.

Over all hangs the pervading odor of creosote.

"It's in sad shape," Carey Pafford, environmental health director, said Thursday.

"The rain has created a condition now, it's worse than it was."

Rain Wednesday night raised the creek level, and helped black ooze move faster down the stream.

A black tar-like substance, apparently creosote, was dumped into the creek eight days ago. The health department says a contractor, Raymond I. Tassinari, allowed or caused the poltution.

The material was dumped into the creek west of Main Street, reportedly at the old Cabot Corporation site at 23rd Boulevard.

Heavier than water, it moved slowly for several days, on the creek's sand bottom. Dogs or children playing in the creek came out covered with black, sticky coze, until mothers and pet owners discovered the problem and kept their charges away.

Wading birds, turtles and other wildlife which can live out of water fled the stream. Fish were killed, and Thursday were floating on the water surface in the marshy area east of Littlewood School and at Kanapaha Sink, where the stream drains underground southwest of Gainesville.

Hogtown Creek drains most of western Gainesville and its suburbs.

At Stephen Foster Elementary School, black ooze cover the stream bed and the odor of creosote is strong at the children's nature trail. The trail, built by the Audubon Club for the school, isn't being used until spring, said L. D. Mannings Jr., the principal.

At the spillway near 34th Street, the pollution has foamed up into a dark gray mass, three feet deep, 20 feet wide and 40 feet across.

Downtream from the spillway, the stream looks like dirty, black, soapy laundry water.

"It's not going to be a permanent thing," said Pafford. "But I think we'll be seeing the effects for several months to come."

He added that all the fish have been killed, and the stream may have to be restocked.

"It's going to affect certain plants. There are some that will grow.

"But as far as the normal plant life along the stream, I think it's going to affect it."

"We have had many, many complaints. They're all the same...the oil, the odor, what's going to happen to the wildlife, and how long is it going to last."

GAINESVILLE SUN, Nov. 3, 1967

Destroying Environment

EDITOR, Sun: Gainesville residents in the last week found themselves on the "receiving end" in the two worst cases of air and water pollution that this city has probably ever experienced. Most of us may not have noticed the incidents but to hundreds, maybe thousands, of unsuspecting city and county dwellers the experience was and still is a very unpleasant one. Anybody who has any doubts should make an inspection trip along Hogtown creek, which for weeks, maybe months will serve as a monument to man's ability to wantonly destroy his environment.

It is significant that, according to the newspaper stories, in both instances the pollution source is the same — the old Cabot facility now owned by a local contractor. When this "smelly" facility ceased its operations a year ago nobody in Gainesville mourned. Few suspected that it would be capable of giving the city this "farewell greeting." The incidents have been briefly described in this newspaper. In the second and most serious one, which took place last Thursday, large quantities of creosote in a holding pond were unceremoniously dumped into Hogtown creek, resulting in the present mess and presently finding their way to our subterranean water supplies. The damage is of such proportions that Alachua county health officials found reason to sign complaints against the present owner of the plant. It will be interesting to see the final outcome of the case. It is unfortunate that our present laws are so lenient that a "public-be-damned" act of these dimensions will hurt the pocketbook of the guilty party to the maximum extent of only $1,000, a circumstance that makes it economically advantageous to get rid of industrial wastes in this manner.

There may be some excuse for the fact that we have tolerated, in our past ignorance, the total destruction of Lake Erie and Mississippi River to mention just two of our once magnificent waters. It is less understandable, at least to this writer, how it is possible in an educated modern society, for a city the size of Palatka to accept, year after year, that its air on several days of the average week be polluted to the point that it is hardly fit for a human being.

For a city like Gainesville that has had the good fortune to grow to its present size relatively unpolluted it would be utterly irresponsible and self defeating not to be on vigilant guard against incidents of the above type. The residents of this community should understand that only strong local outcry against our local polluters and strong support for and encouragement to our pollution fighters are effective. Our county may soon have the doubtful honor of housing phosphate plants, and now is the time to make sure that Gainesville does not intend to accept the quality of air that Bartow and Lakeland settled for in an earlier era.

OLLE I. ELGERD

TAMPA TRIBUNE, Jan. 16, 1968

Second Civil Suit Asks Creek Pollute Damages

GAINESVILLE (By Staff Writer) — Filing of a second civil suit for damages has given new life to the three month old controversy over the pollution of Hogtown Creek.

Homeowner Thomas A. E. Hart and his wife have filed suit against Raymond J. Tassinari for damages in excess of $5,000 because of the continuing existence of the problem.

The creek was polluted Oct. 26 when holding pens at the old Cabot Carbon Co. property were opened and thousands of gallons of creosote waste flowed into the waterway.

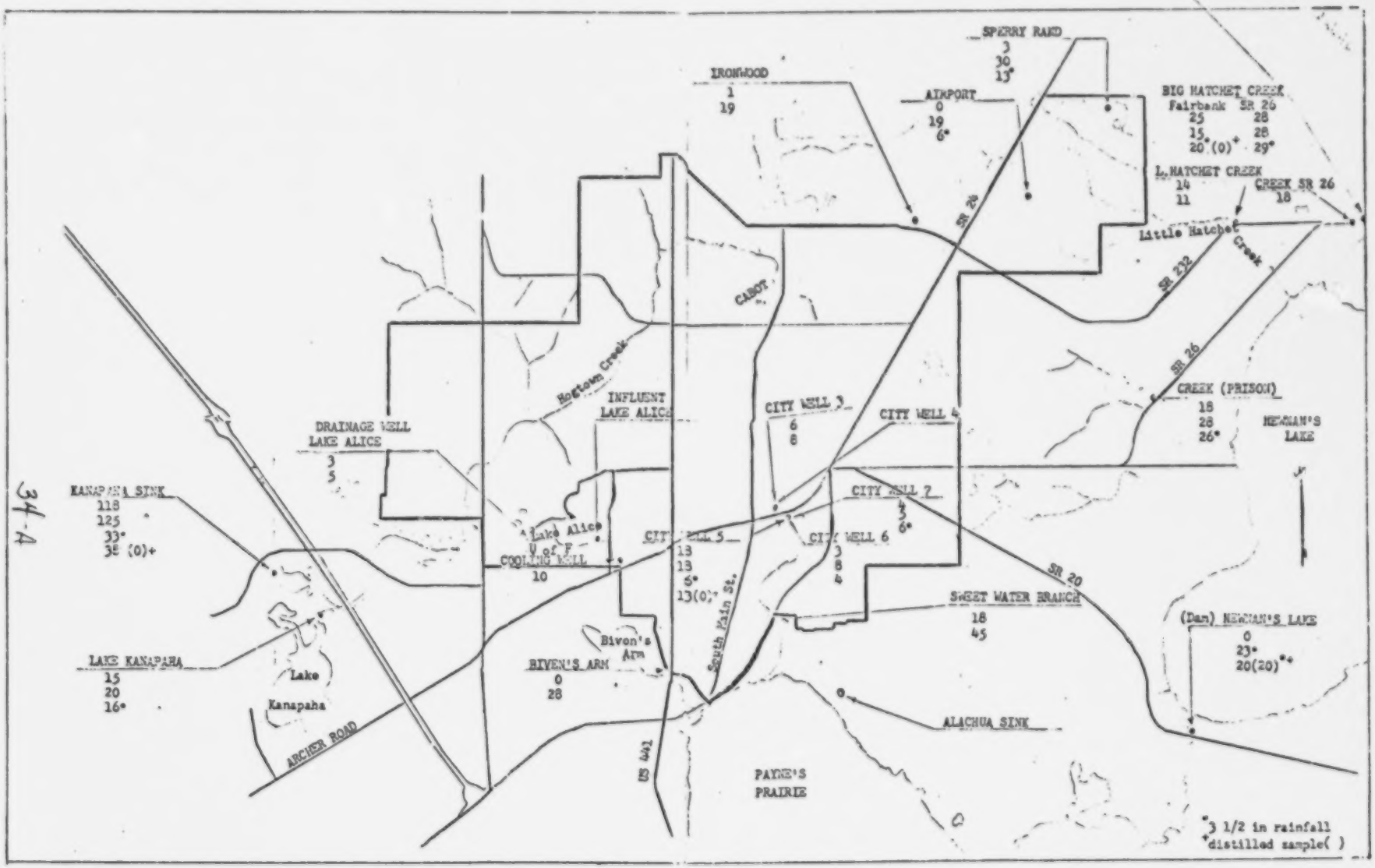
Tassinari was found guilty on municipal charges of pollution and subsequent efforts by the city, county and Tassinari himself have removed much of the substance remaining in the creek.

The Hart suit indicates however, the creek is not yet free of the material as it charges "the air surrounding said home has been rendered obnoxious and unhealthful" and that the damage is "continuing and permanent in nature."

Tassinari was clearing the Cabot site, long a city eyesore, when the creosote waste was released. The suit asks that he be enjoined to remove the residue still remaining in the stream.

Little damage was apparently done to the stream itself but the tar-like mass has given off a definite creosote odor and caused consternation among property owners and wildlife organizations.

Attorney for the Harts is William R. Burwell of Gainesville. The suit declares that the Harts have suffered deprivation of enjoyment of their property for use as a home.



34-A

Fig. 9 - Phenol Determinations at 18 Sampling Points in the Gainesville Area. Results in ppb.

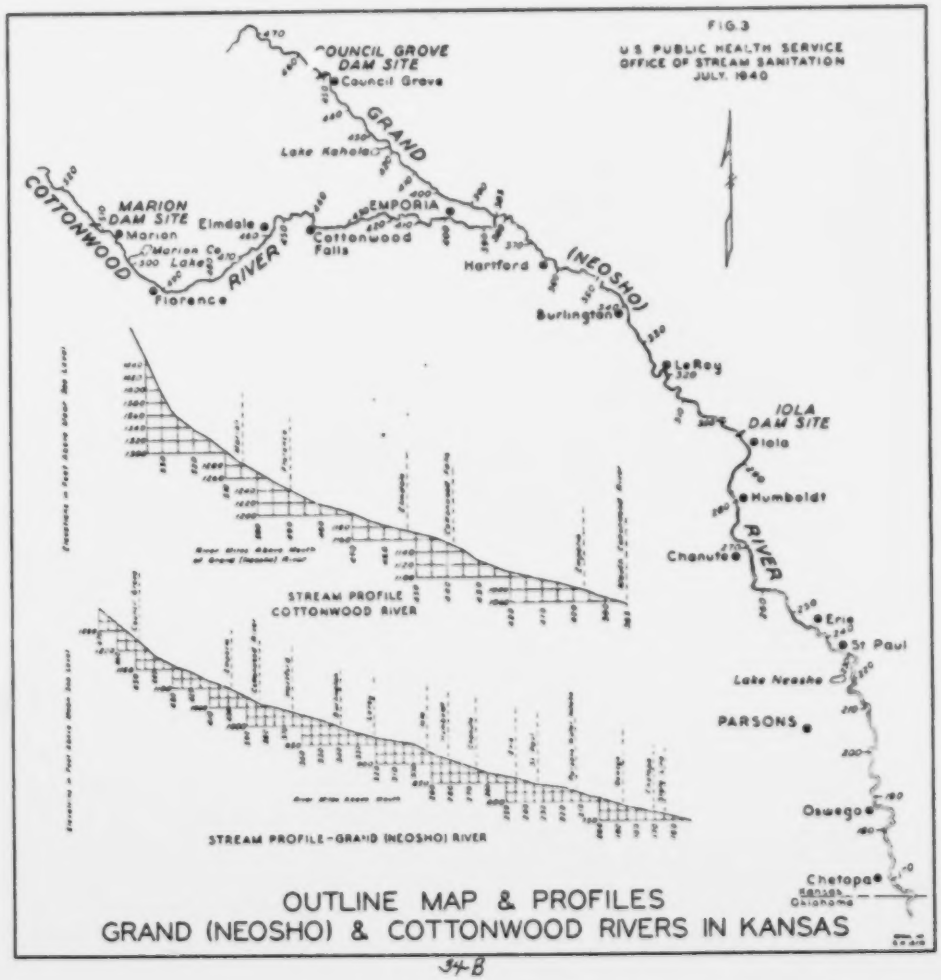


FIG.3
U.S. PUBLIC HEALTH SERVICE
OFFICE OF STREAM SANITATION
JULY, 1940
COUNCIL GROVE DAM SITE
Council Grove
GRAND
Lake Kahola
COTTONWOOD
MARION DAM SITE
Elmdale
Marion
Marion Co. Lake
RIVER
Florence
EMPORIA
Cottonwood Falls
Hartford
NEOSHO
Burlington
LeRoy
IOLA DAM SITE
Iola
Humboldt
Chanute
RIVER
Erie
St Paul
Lake Neosho
PARSONS
Oswego
Chetopa
Kansas
Oklahoma
STREAM PROFILE COTTONWOOD RIVER
STREAM PROFILE - GRAND (NEOSHO) RIVER
OUTLINE MAP & PROFILES
GRAND (NEOSHO) & COTTONWOOD RIVERS IN KANSAS

34 B

34 B

to pH 10 ± 0.2, adding the two reagents, allowing the samples to stand for 15 minutes, and then reading the absorbance at 510 mμ, using a standard curve prepared in the same manner. In the third method, distillation is omitted and a measured volume of sample is strongly acidified with HCl and extracted three times with petroleum ether. The combined petroleum ether extracts are washed twice with distilled water to remove the HCl and then extracted three times with 0.5 N NH_4OH. The combined extracts are buffered to pH 7.9 ± 0.1, 4-amino antipyrine and potassium ferricyanide added and the absorbance determined after 15 minutes at 500 mμ. This method has been shown to be most sensitive to para-substituted phenols and in consequence usually yields higher values than either of the other two methods.

In order to save time, our first series of determinations were made at pH 7.9 using the third method. It was soon discovered that the presence of organic color interfered to a significant degree with this method and the distillation of samples was begun. Four samples were run both by distillation and chloroform extraction and by the third method with distillation omitted and petroleum ether extraction at pH 7.9. Of the four samples, three of those distilled showed no phenols, whereas at pH 7.9 the values for the undistilled samples were 13, 20, and 38 ppb. The fourth sample yielded identical values of 20 ppb by the two methods. Data obtained on samples collected at 18 sampling points throughout the study area are shown in Figure 9. At this point, the values are considered to be qualitative only, but do appear to indicate that substances of a phenolic nature are widely distributed throughout most of the study area. Sampling points known to be polluted with the phenolic wastes yielded the highest values, whereas the values found for samples collected at points shown by other indicators to contain little or no pollution gave values no greater than the sensitivity of the method used. The work is being continued.

C. A Preliminary Investigation of Taste- and Odor-Producing Substances Found in the City of Gainesville Water Supply

Introduction

Under certain conditions of chlorination and perhaps of iodination, highly objectionable tastes and odors are produced. The original assumption was that halogenation of certain unknown organic substances takes place, and that it is these halogenated organic compounds that give rise to these tastes and odors. To alleviate or eliminate this condition, the identification of these substances is felt to be of primary importance. This means that their separation and concentration must be accomplished in some manner. Since these substances can be readily detected organoleptically, it can be assumed that they are relatively volatile and can be removed by distillation.

High-vacuum Distillation

A high-vacuum system was obtained, consisting of a vacuum pump,[a] a 3-neck two liter distilling flask, and a cold finger condenser.[b] Liquid nitrogen was used as the coolant. Each of several batches of chlorinated and iodinated water in five-gallon samples were concentrated upon the cold finger to a final volume of 500 ml. This concentrate was yellowish with a strong halogen odor. Portions of this concentrate were extracted with methylene chloride and evaporated. Aliquots were used for gas chromatographic separation on standard columns such as OV-1 or SE-30. Several unidentified peaks were observed.

At this stage in the investigation, it was hoped that the use of a GC/Mass Spectrometer would be available, but due to shipping delays it was not available. The collected samples are being kept under refrigeration until the equipment is available.

Gas Chromatographic Analysis of Chlorinated Phenols

In view of this delay, a different approach to the solution of the problem was sought. It is known that common malodorous substances are the sulfur compounds such as organic sulfides and mercaptans, and phenol and its derivatives. According to C. Fred Lee, "By far the most notorious organic compounds found in water which increase the tastes and odors in the water upon chlorination are phenol and some of its homologs."

Since phenols have been isolated in the city water system, it was felt that we should investigate the levels of the various chlorinated and free phenols in selected locations within the water system. Again, as a matter of suitability, gas chromatographic methods of analysis were considered.

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[a] W. M. Welch Mfg. Co., Model No.

[b] California Laboratory Equipment Co., Model C Evaporator.

Several methods of gas chromatographic analysis of phenol derivatives have been published. The method of Kolloff, et. al. was investigated. The column packing was prepared, as described in the above publication, by evaporation of a methanol-Carbowax 20M - H_3PO_4 solution slurried with the solid support[c] in a rotary vacuum evaporator[d] placed in a hot water (80°C) bath. The packed column was conditioned and purged as described, except that argon was used instead of helium. A Research Specialties, Model 600 gas chromatograph with a hydrogen flame detector was used.

The following compounds were investigated:

o-CP	orthochlorophenol
B	phenol
2,6-DCP	2,6-dichlorophenol
2,4-DCP	2,4-dichlorophenol
2,4,6-TCP	2,4,6-trichlorophenol
p-CP	parachlorophenol
m-CP	metachlorophenol

The separation and the retention times agreed very well with those reported by the above authors. However, the writer is in agreement with a statement made in the same publication: "Loss of substrate is substantial, as indicated by reduced retention times." Even though Kollof et. al. were able to use their column for better than six months, the column prepared in this laboratory began to lose its efficiency within two weeks of continuous operation as indicated by continuous reduction of retention time. It is felt that in an investigation of a relatively unknown system, such as the actual measurement of the chlorinated phenols in the city water system, a variable analytical tool could easily lead to misleading results. Because of this, a different liquid phase would have to be found.

The "Free Fatty Acid Phase," (FFAP)[e] was found to be eminently suitable for this separation. As a first criterion, the thermal stability for this phase is claimed to be up to 300°C as compared to the 250°C for the Carbowax 20M.[f] This alone would assure a satisfactory life expectancy, since the common operating temperatures for the compounds under investigation are 180-220°C. In addition, the excellent separation of the free fatty acid in our laboratory has some commendable features. A sharp peak is obtained for acetic acid and butyric acid as well as palmitic acid, using a temperature programmed system. The separation of the available free and chlorinated phenols is, as expected, of the same order as for the Carbowax 20M-H_3PO_4 system. The retention times of the free and chlorinated phenols investigated are recorded in Table 12.

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[c] Gas Chrom Q, Applied Science Labs. Inc., P.O. Box 440, State College, Pa.

[d] Rotating Vacuum Type, Rinco, purchased from Fisher Scientific Co.

[e] FFAP is a reaction product between Carbowax 20M and 2-nitro-terephthalic acid developed by Varian Aerograph, 2700 Mitchell Drive, Walnut Creek, California.

[f] Carbowax 20M obtained from Applied Science Labs, State College, Pa.

Table 12

Compound	Retention Time, minutes
o-CP	1.8
B	3.0
2,6-DCP	3.9
2,4-DCP	5.1
2,4,6-TCP	8.3
p-CP	11.1
m-CP	11.2

Operating conditions: 4 ft x 4 mm i.d. glass column.
Argon flow: 20 cc/min (estimated).
Injection port temp. 280°C, Column temp. 195°C.
Hydrogen flame detector, 20% FFAP on Gas Chrom. Q, 60/80 mesh.

Discussion

At present, work is in progress to extract the phenolic substances present in the water samples obtained at different locations and to separate and identify these different phenols, if present. The extraction method used consists of extracting a 500 ml sample of acidified water with petroleum ether, evaporating the ether fraction under vacuum at room temperature, and injecting an aliquot into the described gas chromatographic analysis system as shown in Table 12. It is impossible to draw any definite conclusions at the present time but it appears that petroleum ether may not be the best solvent, since it is very difficult to obtain. The method of phenol concentration mentioned by Ballinger is now under consideration.

It has been possible to extract and measure chlorophenols added to distilled water at about 50% efficiency using methylene chloride as the organic phase. See Figure 10. Further work is indicated to improve this method. Adsorption columns, such as Sephadex, charcoal and silicic acid, and inorganic ion exchange columns might be used to advantage. Freeze concentration methods as described by Black and Christman could conceivably be used.

In conclusion, there appears to be no difficulty in measuring chlorophenols in the nanogram range. The problem to be solved is the development of an efficient method of concentrating the chlorophenols.

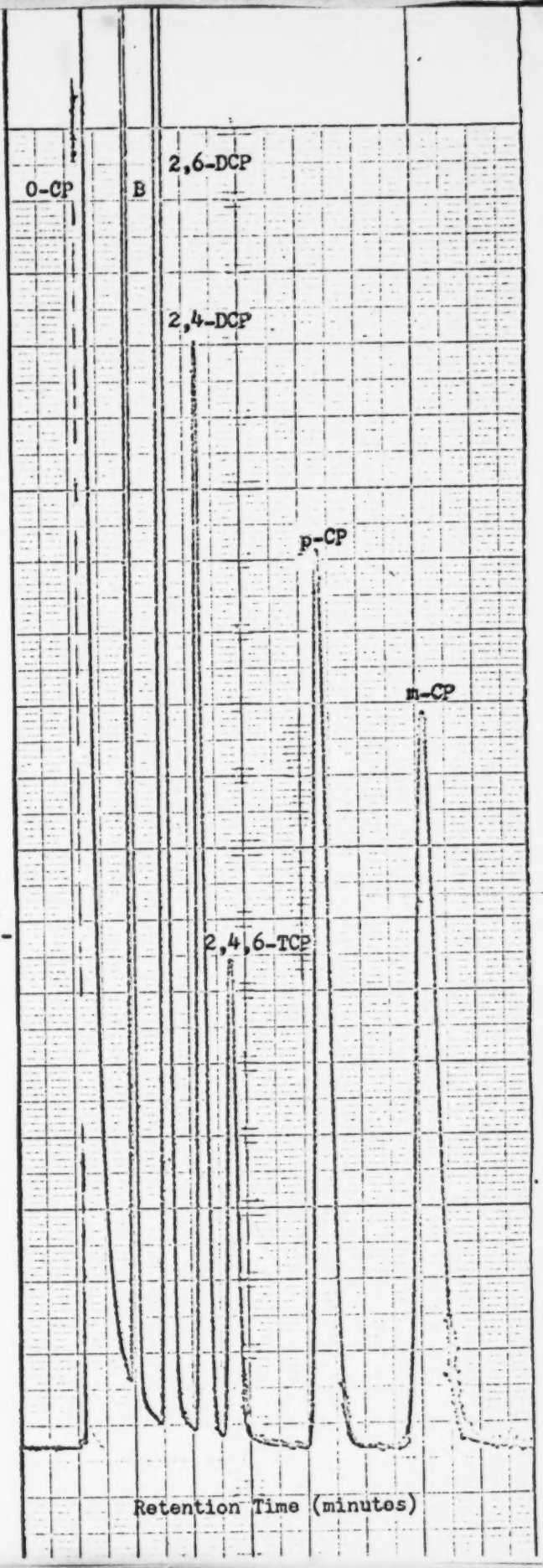

Fig. 10 - Gas Chromatogram of Phenol and of Three Mono-, Two Di- and One Tri-Substituted Chlorophenols.

D. Taste and Odor

Threshold level studies in conjunction with gas chromatographic analyses are being carried out in order to determine the source of taste and odor producing compounds which are present in the Gainesville water supply.

At this time, however, only the threshold levels of the various disinfectants used in water treatment have been completed, namely, (1) iodine, chlorine and chloramine in distilled water, (2) iodine-treated well water, and (3) Gainesville treated water, chloramine.

Other parameters of study will include:

1. Threshold odor numbers for a number of unpolluted and polluted waters treated both with chlorine and with iodine.

2. Study of methods for concentrating these materials, which are present only in mocro-concentrations, for subsequent identification, if possible, by gas chromatographic methods.

3. Correlation of the data obtained in (1) and (2) above in an effort to identify those compounds whose presence in water is most objectionable to the consumer.

4. A second plant-scale test of iodine, if suitable conditions can be realized.

Preliminary data indicate that iodine can be detected at significantly lower concentrations in unbuffered distilled water than either chlorine or chloramine. The odor threshold for iodine at 25°C is 0.06 mg/l compared to 0.19 mg/l and 0.23 mg/l for free chlorine and chloramine, respectively. However, the sequence of taste thresholds for iodine, free chlorine and chloramine are reversed, being 2.0 mg/l for iodine, 0.5 mg/l for chlorine, and 1.0 mg/l for monochloramine.

An increase in threshold odor number from 2 to 8 was observed after 24 hours when iodine was added to an unpolluted well water. However, the type of odor produced during this retention period was not similar to that produced in the iodinated Gainesville water.

Distillation of iodinated Gainesville water indicates that the odor-forming compounds are volatile as the odor in the distillate is similar to that of iodinated Gainesville water from the tap, whereas the undistilled fraction remaining in the flask has no odor nor does the addition of more iodine produce an odor.

The Lowell Prison Study

The iodine feed level has been continuously maintained at 1.0 ppm and unless the tests to be run by Dr. Thomas indicate a need for reducing the iodine level, this concentration will be continued. To date, there have

been no adverse effects from iodination, and upon completion of the last series of medical examinations, this phase of the study will be concluded and the complete operation and maintenance turned over to the state institution. Every effort will be made to see to it that the operation is continued under competent supervision since it is believed to be the first of its kind in the world. The assistance of the Florida State Board of Health in this effort should be most helpful and will be requested.

It is interesting to note that of 64 samples from well No. 1, 25% confirmed; of 64 samples from well No. 2, 75% confirmed; while only 6% of the 64 samples from well No. 3 confirmed. Of the 384 samples from the distribution system over the entire period only 3.4% confirmed.

E. Problems in Disinfection of Swimming Pool Water

Compatibility of Algicides with Halogens

Iodine has been shown to be as effective bacteriologically as chlorine and in many respects has demonstrated superior qualities. Residuals are more stable, costs are less, and eye burn is markedly decreased; however, our main problem has been algae control while using iodine as a disinfectant. This problem exists with chlorine as well, only not as seriously. Superchlorination generally destroys the less resistant strains of green algae, but the so-called "black algae" are even resistant to high concentrations of chlorine.

The following is a partial summary of our studies so far this year and is by no means complete, as we are improving our techniques and will repeat many of the tests now that some base lines have been established.

In-Pool Studies

A pre-selected group of children have been examined at the University of Florida Eye Clinic within one-half hour after a two-hour swim practice to determine the effects on the eyes from the various disinfectants and the compatibility of these disinfectants with a mercurial base algicide and a copper base algicide. A (t) test was applied to the means of Keratitis values for each of the algicides and disinfectants. See Tables 13 and 14.

Table 13

In-Pool Comparison of Disinfectants and Algicides on Keratitis Irritation

Treatment	Number Eyes Examined	$\bar{X}$	Halogen Range ppm	pH Range	Algicide Range ppm
Chlorine	48	1.63	0.3-0.6	7.2-7.4	None
Chlorine + Mercurial	40	3.49	0.8	7.3-7.5	0.01-0.08
Iodine + Mercurial	44	2.22	0.7-1.6	7.2-7.7	0.01-0.08
Iodine Copper Sulfate	18	1.58	0.9	7.3	0.25

$\bar{X}$ = mean of Keratitis values.

As can be seen from the above table,

1. The mercurial is more irritating when used with either chlorine or iodine than when chlorine is used alone or iodine with copper.

2. Chlorine with the mercurial is more irritating than iodine and the mercurial.

3. Iodine and copper is not significantly different from chlorine alone.

4. At the .05 level we cannot accept the null hopothesis ($\overline{X}\ Cl_2 = \overline{X}\ I_2 + \phi MA$); whereas, at the .01 level we cannot reject this hypothesis; therefore, the difference between means is too small to be discerned at the 99% level.

Table 14

Comparison of (t) Values

95% confidence 2.00**
99% confidence 2.60*

Treatment	(t) Value
Chlorine vs Chlorine + Mercurial	8.27**
Chlorine vs Iodine + Mercurial	2.26*
Chlorine + Mercurial vs Iodine + Mercurial	6.60**
Iodine + Mercurial vs Iodine + Copper	2.37*

Laboratory Studies

Previous studies indicated no eye burn from iodine alone; therefore, we set up experiments in an effort to determine which agent or agents were responsible for this eye irritation.

Agent (s)	Reaction
1. Algimycin + KCl	ppt
2. Algimycin + Cl_2	NR
3. Algimycin + KCl + Cl_2	ppt
4. Algimycin + KI	ppt
5. Algimycin + I_2	NR
6. Algimycin + KI + I_2	ppt
7. "A" + KI + I_2	ppt (slight)
8. "B" + KI + I_2	NR
9. ϕMA + KI	ppt
10. ϕMA + I_2	ppt

"A" = ethylene glycol + n=butyl ether)
"B" = n-coco amine) inert ingredients

Both KCl and KI gave precipitates with the algicide and the KI gave a precipitate with only the phenyl mercuric acetate.

Although the concentrations in the pool are much lower than those tested in the laboratory, we feel the formation of double salts (i.e., $2HgI_2.2KI.3H_2O$) occur in the pool, causing corneal toxicity and inflammation of the conjunctival tissue; however, these salts appear to increase the bactericidal effects significantly.

Algimycin was tested in the Faculty Club pool without any other disinfectants to test its effectiveness as a bactericide. The swimmers did not experience any eye burn, but the bacteriology was not satisfactory. This study should be run in the laboratory and if positive results are shown, tested again in the pool using a different feeding technique.

Rabbit Tests

Preliminary screening tests on the various algicides and disinfectants were conducted in order to predict the possible effects on the children. Solutions containing algicides and disinfectants at pool concentrations were squirted continuously for one hour into the eyes of the test animals. Our methods were admittedly somewhat crude at first, but we now have special eye cups on order so that a continuous flow of solution can be maintained at a constant rate and pressure.

All of the tests will be repeated using larger numbers of specimens, but the data presented here at least indicate the animals can be used effectively for screening purposes before actual pool studies are conducted.

We found the rabbit eyes to be somewhat more oily than the human eye, and had to double the actual concentrations that would be used in the pool in order to get a more positive correlation.

Table 15

Comparison of Disinfectants and Algicides on Keratitis Irritation in Rabbits

Treatment	Number Eyes Treated	$\bar{X}$	Halogen ppm	pH	Algicide Range ppm
ϕMA	12	0.58	None	7.0	0.02-0.08
ϕMA + Cl_2	12	0.67	0.55	7.0	0.02-0.08
ϕMA + I_2	12	1.5	0.71	7.0	0.02-0.08
Cu^{++} + I_2	36	1.8	0.70	7.0	0.6-2.0

$\bar{X}$ = mean of Keratitis values

The rabbits appear to be more sensitive to iodine than humans, as the means show more irritation when iodine is used with either mercury or copper. The low number for chlorine is attributed to the fact that chlorine is very unstable and reacts immediately with the tears and oils present in the rabbit's eye. The new technique using continuous irrigation will hopefully eliminate such errors in our re-testing study.

Devitalization of Microorganisms - Laboratory Studies

Method - The technique of Ortenzio and Stuart has been employed to determine the resistance of Escherchia coli, Streptococcus fecalis, Staphylococcus aureus, and Staphylococcus epidermidis to iodine and free chlorine concentrations. The effect of ammonia on bactericidal effectiveness of chlorine was studied using S. aureus and S. epidermidis. Also, the effect of pH on the action of the two free halogens was investigated using the staphylococci as test organisms.

Results - The relationship of 99 percent devitalization time and free halogen concentration for Streptococcus fecalis, Escherichia coli, Staphylococcus epidermidis and Staphylococcus aureus showed good fit ($r = 90\%$) when the method of least squares was used to fit lines to log-log plots of 99

percent devitalization time vs halogen concentration (Figures 11 and 12). Death curves for the bacteria tested tended to become good approximations of exponential death curves at each halogen concentration except at low halogen levels where some lag occurred for the first 30 seconds. Marked differences in resistance were observed among various genera as well as differences between their resistance to free chlorine and iodine. S. epidermidis seemed at first to be somewhat more resistant to both disinfectants than S. aureus; however, this difference was found not to be significant by means of covariance. Iodine was as effective as chlorine in devitalizing both Staphylococcus species at pH 7.5 and 25°C. Both the Staph species were more resistant to the action of chlorine than either E. coli or S. fecalis.

E. coli appears to be the least resistant of all species studied to both iodine and chlorine, however, it is slightly more resistant to iodine than chlorine. Streptococcus fecalis is the most resistant organism to iodine of those studied.

Effect of pH - Laboratory experiments on resistance of staphylococci to chlorine and varying hydrogen ion concentration showed a lowered rate of die-off as pH increased. At pH 6.0 chlorine was more active than iodine; however, at pH 7.5, the usual pool pH, their effectiveness as disinfectants was not significantly different. There was a decrease in the effectiveness of both halogens as pH increased, but the diminished biocidal effect with chlorine was much greater than with iodine. This is due to the loss of HOCl by ionization to OCl^- which is ineffective as a bactericide at high pH. Because HOI does not ionize to a great extent, iodine was much more active than free chlorine at an initial pH of 9.5. The effect of pH on the resistance of S. aureus to concentrations is shown in Figures 13 and 14.

Effect of ammonia - Resistance of both species of Staphylococcus was greatly increased by the addition of ammonia which combined with the chlorine. The percent survival after five minutes contact with combined chlorine indicates that this form is much less effective against staphylococci than free chlorine or iodine. Table 16 shows the percent survival of S. aureus devitalized with combined chlorine. A different relationship may govern the action of combined chlorine than the action of free chlorine against staphylococci because the plot of log percent survival vs log concentration of combined chlorine is non-linear. Increasing pH reduced the effectiveness of combined chlorine for both organisms; however, S. aureus appeared to be slightly less resistant to the combined form than S. epidermidis at all three pH's studied.

Summary of Pool Bacteriology

The results of iodination of the University of Florida swimming pool over a period of three years (Table 17) have shown that iodine is an effective microbicide. The percentage of confirmed coliforms has been much less than the maximum allowed in the 1962 USPHS Drinking Water Standards. Fecal streptococci are also controlled very well. In these respects iodine is fully as effective as free residual chlorine as a disinfecting agent. From a more limited number of samples staphylococci seem to be controlled more effectively by iodine than by chlorine. The higher plate counts encountered during iodination are suspected to be caused by organisms of the Pseudomonas alcaligenes

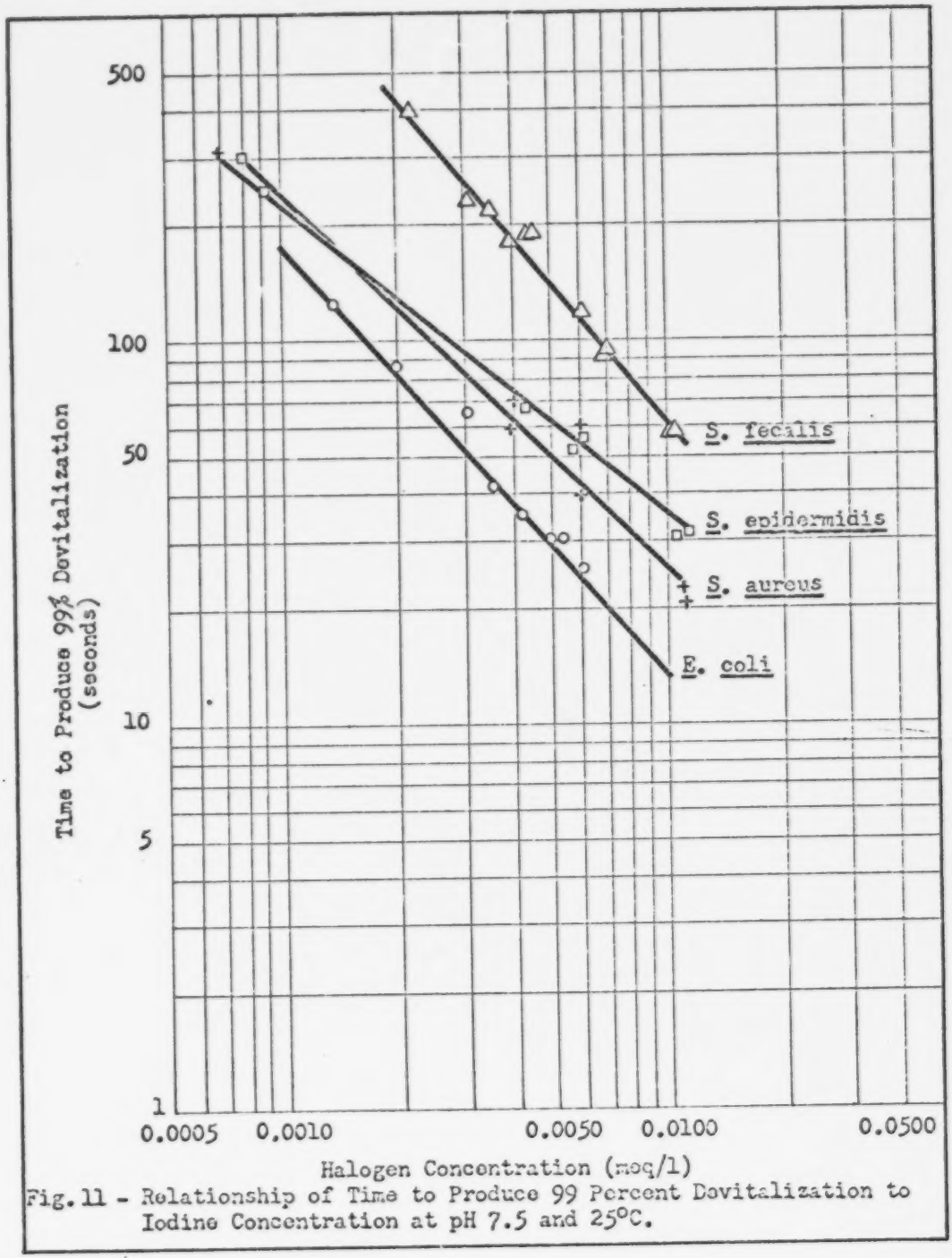

Fig. 11 - Relationship of Time to Produce 99 Percent Devitalization to Iodine Concentration at pH 7.5 and 25°C.

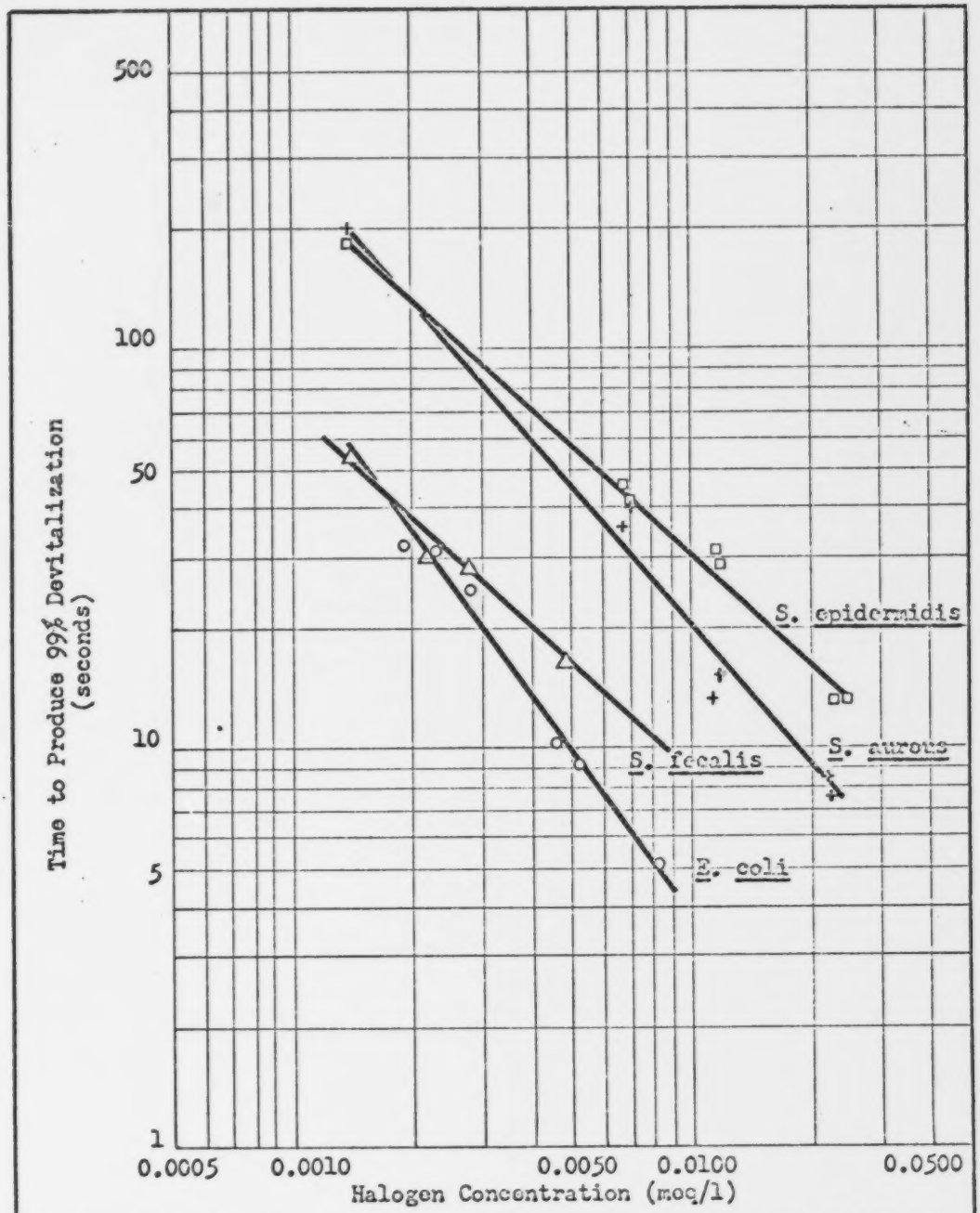

Fig. 12 - Relationship of Time to Produce 99 Percent Devitalization to Free Chlorine Concentration at pH 7.5 and 25°C.

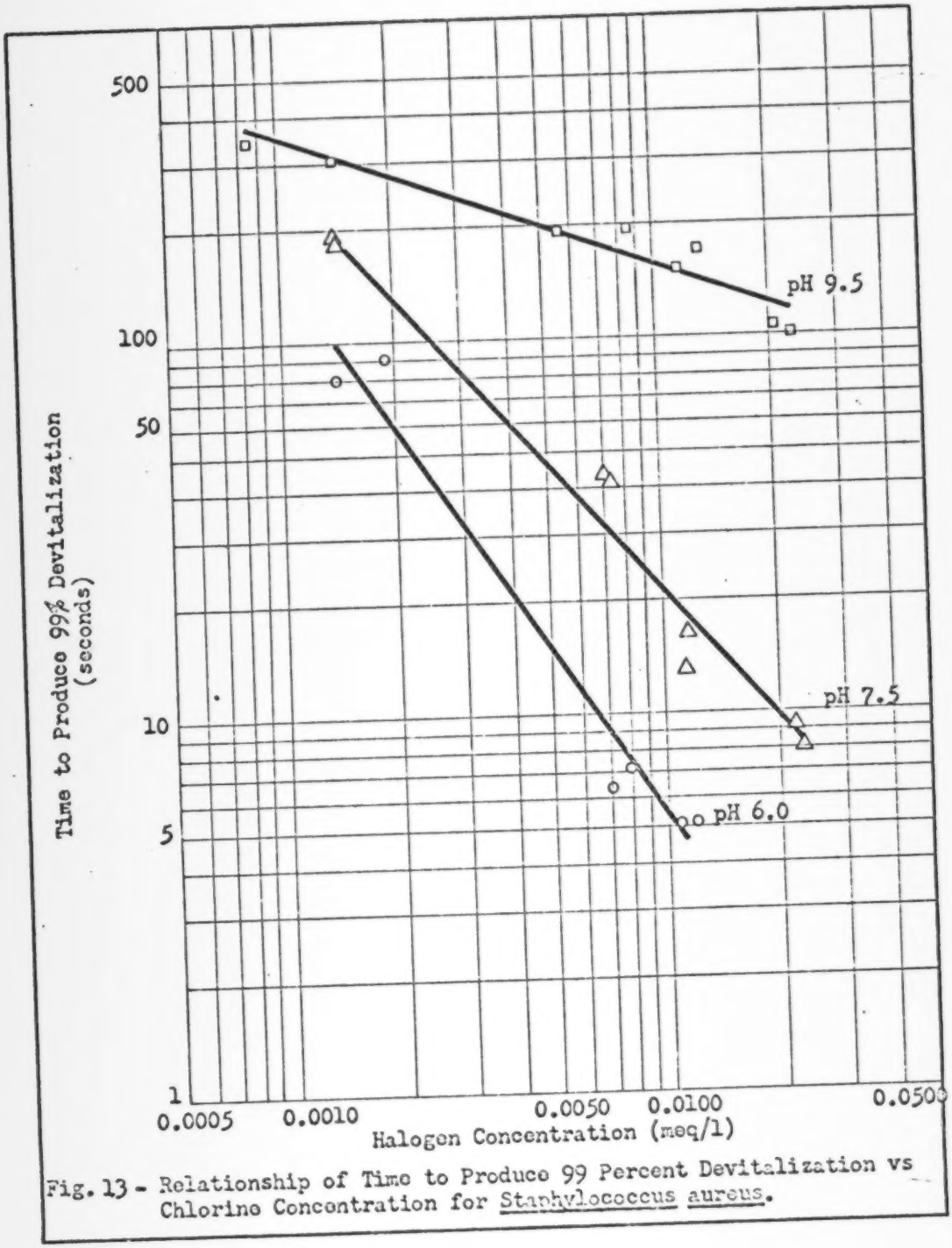

Fig. 13 - Relationship of Time to Produce 99 Percent Devitalization vs Chlorine Concentration for Staphylococcus aureus.

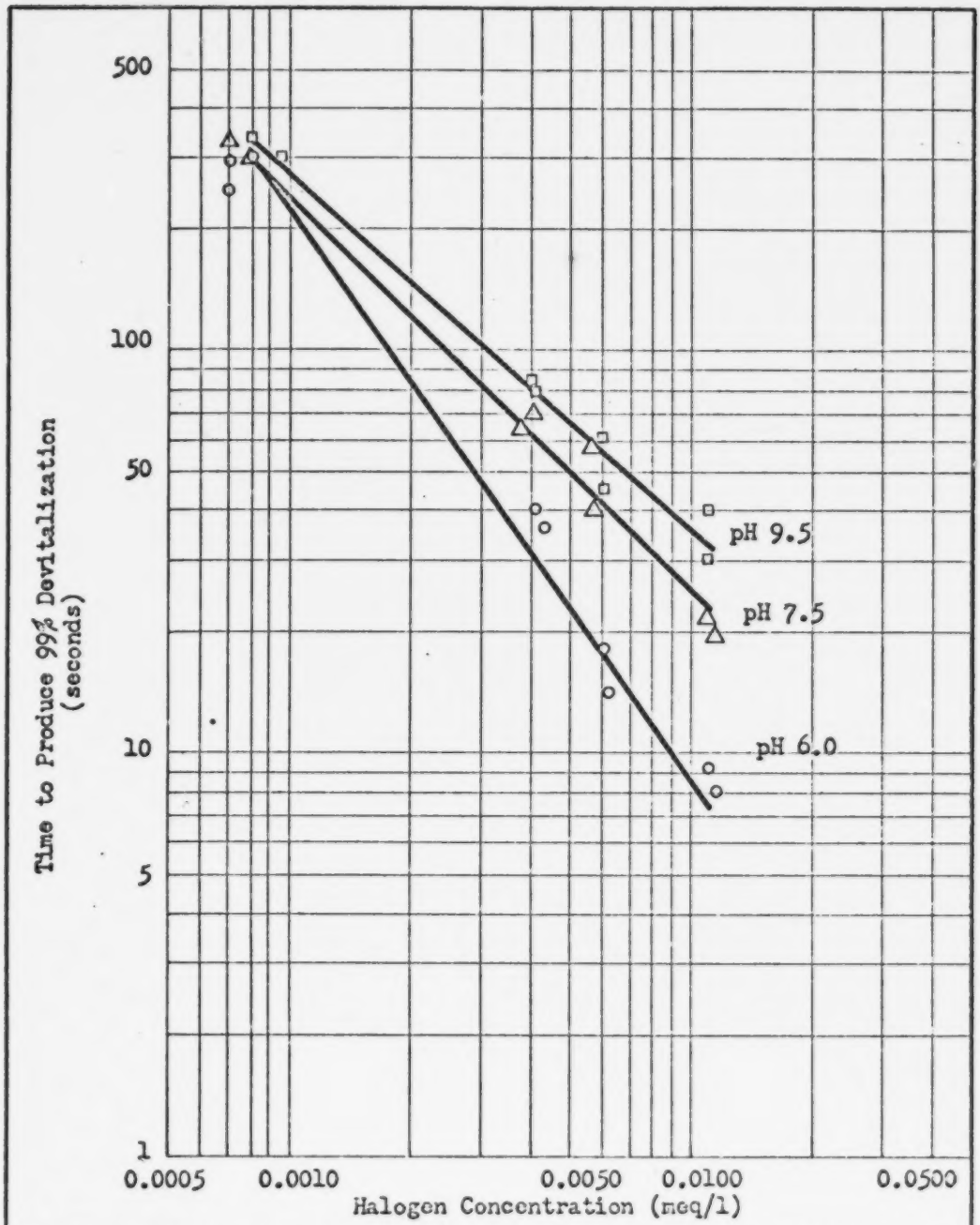

Fig.14 - Relationship of Time to Produce 99 Percent Devitalization vs Iodine Concentration for Staphylococcus aureus.

Table 16

Percent Survival of *Staphylococcus aureus* After Five Minutes Contact With Combined Chlorine[1]

pH 6.0		pH 7.5		pH 9.5	
Residual meq/l	Percent Surviving	Residual meq/l	Percent Surviving	Residual meq/l	Percent Surviving
0.0012	76.3	0.0012	96.0	0.0014	98.0
0.0016	78.2	0.0014	96.0	0.0014	98.0
0.0028	18.0	0.0025	32.0	0.0036	78.5
0.0036	15.0	0.0028	28.1	0.0042	74.2
0.0118	0.81	0.0112	4.7	0.0118	36.0
0.0126	0.63	0.0114	5.0	0.0122	38.7
0.0290	0.001	0.0285	0.19	0.0280	23.1
0.0295	0.001	0.0295	0.25	0.0290	24.4

[1]Measured as Cl.

Table 17

Effectiveness of Iodine and Free Chlorine for Disinfecting Swimming Pool Water

	Iodine	Chlorine
Total number of samples	790	439
Desired residual range, ppm	0.6 - 0.8	0.4 - 0.6
Samples confirming for coliforms	2%	3%
Samples confirming for fecal streptococci (%)	3%	2%
Average number of staphylococci per 100 ml (%)	3.5*	46**
Median 48-hour plate count	210	5

*Based on 60 samples

**Based on 54 samples

or Alcaligenes fecalis group which have been found in large numbers in iodinated pools by Favero and Drake. These organisms are common soil organisms and appear to be of no sanitary significance.

In general, it was found that the plate count would build up gradually from numbers below 100 to numbers greater than 2,000 organisms per ml over a period of time, dependent upon the amount of dust falling into the pool. During the fall of 1966, very high plate counts were found which were thought to be caused by dust contamination of the pool from nearby construction. No evidence of the occurrence of Pseudomonas aeruginosa, a potential pathogen, was found until after the addition of a leading quaternary ammonium salt as an algicide in conjunction with the iodine. Within one week after the initial application of the quaternary, Ps. aeruginosa was evident in many of the fermentation tubes used for coliform determination. This organism is very common in soil and water and is exceptionally resistant to many disinfecting agents. Favero and Drake have on a very few occasions isolated this bacterium from iodinated pools, and therefore this organism is included in this summer's study.

In the instance above, Ps. aeruginosa disappeared from the lactose after burning out with chlorine but reappeared immediately upon addition of iodine indicating that there was a reservoir of infection that the chlorine could not control. Ps. aeruginosa has been isolated by Cothran and Hatlen in both iodinated and chlorinated pools, although it is not known whether this was a free chlorine residual. Favero and Drake found this organism in a private pool using stabilized chlorine and very infrequently in pools using iodine. Our work has found Ps. aeruginosa in 8.2 percent of samples taken from pools using I_2 (total 182 samples), but 0 percent from pools using free chlorine (total 82 samples). In the case of chlorine, however, an attempt to maintain a 24-hour residual was made when mercurial algicide, which enhances effectiveness of both I_2 and Cl_2 was used in the pool which was intensively sampled, and there was a very light load in the University pool during the sampling period. The evidence seems to indicate that this organism warrants study as an indicator organism, as it has been implicated in ear infections which were linked to pools.

Effect of the Algicides on Bacteriology

The mercurial algicide appears to enhance the activity of iodine and chlorine (Tables 18 through 21). There is a marked reduction in numbers of staphylococci plate count and Ps. aeruginosa with both disinfectants when this algicide is employed.

$CuSO_4$, however, appears to enhance the growth of Ps. aeruginosa and plate counts are beginning to rise at this time. However, this may be due in part to operational problems at the pool.

The use of the mercurial above as a bactericide proved unsatisfactory. Coliforms, Ps. aeruginosa, and enterococci were isolated from most of these samples. Plate counts ranged from 10^4-10^5 and the numbers of staphylococci increased to upwards of 49/100 cc.

Table 18

Iodine alone:	Sampling period:	June 15-23, 1967
Faculty Club Pool	No. samples:	30
	pH range:	7.5 - 7.7
	Residual range:	I_2 0.3 - 1.1
	Bather load:	Average 251

Organism	Average	Range
Confirmed coliforms (%)	0	-
Confirmed enterococci (%)	0	-
Confirmed Ps. aeruginosa (%)	13.3	-
Total staphylococci per 100 ml	14.4	2 - 34
48 hour standard plate count	1900[1]	80 - 9700[2]

[1]Median rather than average due to large range.

[2]Only 6 less than 500 (20%).

Table 19

Iodine and algimycin:	Sampling period:	June 9-15, 1967 June 23-July 25, 1967
Faculty Club Pool	No. samples:	69
	pH range:	7.2 - 7.9
	Residue range:	I_2' 0.0 - 1.9 Hg
	Bather load:	Average

Organism	Average	Range
Confirmed coliforms (%)	0	-
Confirmed enterococci (%)	15	-
Confirmed Ps. aeruginosa (%)	4.4	-
Total staphylococci per 100 ml	5	2 - 42
48 hour standard plate count	57[1]	8 - 1500[2]

[1]Median rather than average due to large range.

[2]Only 6 values 1000 (8.7%)

19 values 200 (27.5%)

(1964 standards for pools 20% greater than 200)

Table 20

Iodine and copper sulfate	Sampling period:	July 27- August 7, 1967
Faculty Club Pool	No. Samples	24
	pH range:	7.2 - 7.6
	Residual range:	I_2 0 - 1.2
		Cu
	Bather load:	Average

Organism	Average	Range
Confirmed coliforms (%)	0	-
Confirmed enterococci (%)	125	-
Confirmed Ps. aeruginosa (%)	32	-
Total staphylococci per 100 ml	6	0 - 42
48 hour standard plate count	50[1]	11 - 130[2]

[1]Median rather than average due to large range.

[2]Well spread over range; however, counts on August 7 have climbed from 500 to 1500 at 24 hours.

Table 21

Free chlorine and algimycin:	Sampling period:	July 17- July 27, 1967
300 Club Pool	No. Samples	45
	pH range:	7.3 - 7.5
	Residual range:	Cl_2 0.3 - 0.1
	Bather load:	Average

Organism	Average	Range
Confirmed coliforms (%)	0	-
Confirmed enterococci (%)	0	-
Confirmed Ps. aeruginosa (%)	0	-
Total staphylococci per 100 ml	(1)	
48 hour standard plate count	2	1 - 4

[1] Only one set of staphylococci samples yielded a count greater than 1 per 100 ml., that being 16.

As soon as positive samples were found, the pool was burned out with chlorine. During the sample period, however, only a combined chlorine residual was carried. As can be seen from the report sheet, a tremendous improvement in the bacteriology occurred. Last year's study showed that combined chlorine was unsatisfactory, as counts and indicator organisms built up. Perhaps the algicide still present exerted some effect.

Summary

1. Indications from this study show the need for a change in indicator organisms on swimming pools. The present indicators of unsafe pool water are significantly less resistant to disinfectants, and the pollution load from fecal sources is not as great as from the mouth, nose and skin. These organisms are potential pathogens and occur frequently in improperly disinfected pools which show no indication of coliform and fecal strep.

2. Iodine with the mercury compound controls algae very satisfactorily, meets all bactericidal requirements (even in a very heavily loaded pool), and does not irritate swimmers' eyes any more significantly than a properly chlorinated pool.

3. A screening process with animals gives correlation regarding physiological effects of new chemicals introduced into pools, and compatibility of these chemicals with the common disinfectants employed.

Conclusions

1. More work is needed concerning Ps. aeruginosa as a possible indicator organism.

2. An algicide more compatible with both iodine and chlorine is needed.

3. More sophisticated tests must be made now that preliminary work shows clearly the inadequacies of present pool requirements.

4. Iodine with a mercurial is fully as effective as chlorine. In fact, even inexperienced pool operators can achieve a margin of safety with iodine and mercurial that is not possible with chlorine except under skilled operation. Results from last year's study clearly indicate the hazards that exist from improperly chlorinated pools (see Lincoln pool data on chloramine). Chloramine with the mercurial compound is, however, very effective, as shown by this year's study.

5. Cost of operation using chlorine is about the same as that of iodine with a mercurial compound.

F. Field Study of 95 Pools

A field study was made of the chemical and bacteriological quality of the water of 95 below-ground public swimming pools, 84 of them located along the Atlantic and Gulf coasts of Florida and the remaining 11 in Gainesville. Two were under 20,000 gallons; 28 were from 20,000 to 40,000 gallons; 44 were from 40,000 to 100,000 gallons; 17 were from 100,000 to 300,000 gallons, and four were over 300,000 gallons. Sixty-one were operated by hotels and motels; 16 by apartments; 15 my municipalities; and three by country clubs. Forty-two were disinfected with chlorine gas; 23 with sodium hypochlorite; 16 with calcium hypochlorite, and 13 with chlorinated cyanuric acid. One pool had no equipment for adding disinfectant and there was no chlorine product on the premises.

Parameters investigated included turbidity; type of filter, presence or absence of algae, pH; determination of chlorine residual both by amperometric titration and with orthotolidine; coliform density by both multiple tube and membrane filtration; fecal streptococci; total staphylococci; Pseudomonas aeruginosa; and 48-hour standard plate counts.

Only 31 of the pools met and 64 failed to meet the bacteriological criteria presently set by the American Public Health Association for swimming pool water -- namely, absence of coliform organisms by the multiple tube test; less than two coliform colonies per 100 ml by the membrane filter method; and less than 200 colonies per milliliter by the 48-hour plate count. It should be noted that bather loads were, with few exceptions, well below norma , so much so as to have probably substantially reduced the number of pools showing the presence of the more resistant organisms which we had expected to find.

Only 23 of the pools had a free available chlorine residual of 0.3 ppm or higher, as measured by the amperometric titrator, and of these only 15 met the bacteriological criteria of APHA. An explanation for these results is suggested in the paper.

Forty-one pools had pH values within the recommended range of pH 7.2-7.8. Thirty-one pools had pH values below 7.2, and 23 had pH values above 7.8. The lowest recorded value was an unbelievable pH 3.7 - the highest, pH 9.8.

Thirteen of the pools had combined residuals produced by the action of chlorine on an added stabilizer, cyanuric acid. While the number of pools so disinfected was not large, it may be significant that none of the 13 met all of the APHA bacteriological criteria, even though the average total chlorine residual was 1.44 ppm. Seven had chlorine residuals above 1.0 ppm and three above 2.0 ppm. None showed a measurable free available chlorine residual by the amperometric titrator. This is in sharp contrast to the findings of Swatek, Raj and Kalbus, and in general agreement with the findings of Stuart and Ortenzio, Robinton and Mood, and Fitzgerald and DerVartanian.

The orthotolidine test, performed at pool water temperature by practically all operators, showed a high percentage of the total chlorine as free available chlorine, whether present as chloramine or as a chlorinate cyanurate. Properly performed on samples chilled to 1°C, results are better since the reaction of the indicator with combined chlorine is slowed sufficiently to obtain a "flash" reading, which is most free available chlorine.

There is no known method for measuring what we really wish to know, namely, "free chlorine at pool pH." A residual determined by amperometric titration includes both free chlorine and available chlorine (hypochlorite ion) and is not "free chlorine at pool pH," which is the value needed as the best chemical indicator of bacteriological water quality. This value may be readily calculated by multiplying the value of free available chlorine, as obtained by amperometric titration or by the 1°C OT flash procedure, by a factor which varies with the pH of the pool water. Table 22 gives these factors for the optimum range of pH values. The table also shows values for free available chlorine which should be present to provide a true "free chlorine at pool pH" value of 0.4 ppm.

Table 22

Amount of Free Available Chlorine Required to Provide 0.40 ppm Free Chlorine at Pool pH

pH of Pool Water	Percentage of Free Available Chlorine Present as HOCl	Conversion Factor	Free Available Chlorine Required to Provide 0.4 ppm Free Chlorine
7.2	62.3	1.60	0.64
7.3	57.2	1.77	0.70
7.4	52.1	1.94	0.77
7.5	47.0	2.14	0.85
7.6	41.9	2.37	0.95
7.7	36.8	2.70	1.09
7.8	31.7	3.14	1.26

The high coliform counts in 17 pools are believed to be derived from sources other than human pollution. The Staphylococcus counts were much lower than expected, due to the light bather loads. Pseudomonas aeruginosa was recovered in an alarming number of pools, always when plate counts were high. The membrane filter test is seriously interfered with when plate counts are high and high counts appear to correlate extremely well with poor disinfection practice. Fecal streptococci were present in only a few pools. While more work is needed before a final choice can be made, it seems clear that organisms other than those presently used would be more reliable indicators in evaluating the safety of swimming pool water. Both staphylococci and Ps. aeruginosa should be carefully evaluated for this purpose.

The survey indicates that the operation of public swimming pools is not as good as it should be. In many instances, pool operators knew little more than the simple details of mechanical operation. All too many of them had little or no conception of the significance of pH, or of a chlorine residual, or how to maintain a residual within acceptable limits. Many monthly reports, to be submitted to the Health Department, were found filled out for days in advance.

In conclusion, it should be pointed out that the present recommendation of the APHA with respect to the type and amount of chlorine residual is not clear. In the 1964 edition of "SUGGESTED ORDINANCE AND REGULATIONS COVERING PUBLIC SWIMMING POOLS," suggested ordinance 24.1 reads as follows:

> "Swimming pools when in use shall be continuously disinfected by a chemical which imparts an easily measured, free available residual effect. When chlorine is used, a free chlorine residual of at least 0.4 ppm shall be maintained throughout the pool whenever it is open or in use . . ."

The authors respectfully suggest that the following simple changes would provide a statement exact in its meaning and capable of quantitative interpretation and execution.

Suggestion 1. After the words "free available residual" delete the word "effect."

Suggestion 2. After the words "free chlorine residual" add the words "at pool pH."

If this suggestion should meet with favor, it might be simpler to require a value, which the operator would measure, for each pool pH within the accepted range which will provide a free chlorine residual, of 0.4 ppm at the pH of the pool (Table 22).

Of the 95 pools which we have studied, only 5 had a free chlorine residual at pool pH of 0.4 ppm and all 5 met, not only all of the APHA bacteriological criteria, but also all additional bacteriological parameters established for this field study. We feel that the poor operation observed and the bacteriological results obtained in these pools in Florida would be considered as typical and that similar results would be expected in any other area in which a random sample survey was made.

G. Medical Aspects of an Iodinated Water Supply

Thyroid Function

As of January, 1968, the water supply at the Correctional Institutions in Lowell, Florida, had been iodinated for fifty-one months. At this time there remained in the Institutions only 13 of the original 133 subjects selected for evaluation at the onset of this study in September, 1963. The current re-evaluation in January, 1968, revealed that all 13 subjects appeared to be in

good health, and urticaria had not been noted by any of them. The thyroid gland was moderately enlarged in two of these subjects, but in both an enlargement had been detected previously. In three other subjects the thyroid gland, though not distinctly enlarged, was thought to be firmer than normal by three observers. For months preceding this evaluation iodine had been added to the water supply at a concentration of 1 ppm. The thyroid uptake of a tracer dose of radioactive iodine (I^{131}) varied from 2 to 8 percent in these 13 subjects, and the average total iodide in serum was 7.6 μg/100 ml (observed range 4.9 to 117 μg/100 ml). The average protein-bound iodide was 6.1 μg/100 ml (observed range 4.7 to 8.6 μg/100 ml). Thus, although the percent uptake of I^{131} by the thyroid gland was low, as expected, in subjects ingesting more than one milligram of iodide per day, there was no clinical or laboratory evidence of hypothyroidism.

It is not known whether the enlargement of the thyroid gland in two subjects and the increased firmness noted in three others was the result of compensatory changes induced by prolonged use of iodinated water. The current survey was limited to evaluation of those remaining subjects who had been using iodinated water since October, 1963. It is pertinent to note, however, that no instances of hypothyroidism or manifestations of iodine sensitivity have been observed in other inmates of these institutions during the entire study period.

Plans for Forthcoming Year

In an earlier report we cited evidence that in 15 inmates tested after using iodinated water for three to six months several had a demonstrable inhibition in the transfer of thyroidal iodide to organic molecules (tyrosines). Though these few individuals had compensated for this partial inhibition, it is this effect of exogenous iodide which may result in hypothyroidism in those unable to develop adequate compensatory changes. Therefore, we plan to re-evaluate this aspect of thyroid function in a larger and more representative group of inmates who have now been using iodinated water for several years. In addition, the entire prison population is to be examined for evidence of thyroid goiter. If a significant incidence of goiter is detected, this will be correlated with the duration of incarceration in this prison and compared with a group of similar subjects at other institutions where the water is not iodinated.

3. SIGNIFICANT PROBLEMS AND NEW AREAS OF ACTIVITY

A. The production of intensive tastes and odors during the period of experimental iodination of the Gainesville water supply in 1967, emphasized the importance of a better understanding of the types of compounds which might be produced by the reaction of various types of organic pollutants present in the water with disinfecting concentrations of elemental iodine. The great progress made in recent years in the use of gas chromatography for the identification of micro-concentrations of organic compounds led us to add a series of studies of this type to our program. They are being carried out by Egon Nordstrand, a highly qualified research associate in the J. Hillis Miller Health Center of the University of Florida. Using equipment available to the project without cost, he made substantial progress in constructing columns suitable for this type of work and in preparing spectograms of known chlorophenols and several other compounds whose presence in water might be expected. The laboratory staff prepares for him large samples of chlorinated or iodinated polluted water which is then concentrated by Mr. Nordstrand by one of several methods under study and the concentrates examined. It is hoped and believed that substantial progress will be made in this area of activity during this last year of study, and a number of compounds of both chlorine and iodine identified.

B. It has seemed important to determine the threshold concentration of both elemental chlorine and iodine, not only in pure water but in waters containing various types of organic pollutants. This work is well under way and will be enlarged upon during 1968, using taste and odor panels of 5-10 volunteers. The information will be continuously compared and integrated with that obtained in the chromatographic studies.

C. The important studies of underground pollution which have occupied the major portion of our time during the past year will be continued, and the data obtained should lead to a better understanding of the factors which govern underground pollution in the porous and cavernous limestone formations present in the study area and encountered in many parts of the country and of the world. The results continue to indicate the hazards involved in adding any type of pollutant material to underground aquifers in such situations. The following special examples not referred to previously in the Progress Report emphasize this fact.

On three separate occasions a significant increase (60-90 pc/l) in gross radioactivity was detected by the monitoring system at the University of Florida. Both the campus and city sewage effluents and the city drinking water showed these increases. A period of three days passed before the radioactivity appear in the drinking water after detection in the sewage effluents.

The effluents from the city sewage plant empty into Sweet Water Branch and finally into Alachua Sink. The campus sewage effluent empties into Lake Alice. Both Lake Alice and Alachua Sink are located about 3 miles from the city well field. This means the radioactivity moves through the aquifer at approximately 0.061 ft/sec. It is interesting to note that after a period of extreme dry weather followed by 3 1/2 inches of rainfall, color appeared in city well No. 3 which, before this period, had no color. The time for color to appear was also three days.

D. It is hoped that during the final year of this study iodine may be added to at least one municipal water supply in addition to the Lowell Prison supply whose iodination is now in its fifth year. Keen interest has been expressed by officials of the city of Champaign-Urbana, Illinois, and preliminary laboratory studies looking toward that final objective are now being carried out by a graduate student under the direction of Professor John Austin of the University of Illinois. This was briefly referred to in last year's Progress Report.

E. Swimming pool studies during 1968 will involve two important areas. The first is the search for a new algicide which will be compatible with iodine. Our work over the past several years has conclusively demonstrated the overall superiority of iodine over chlorine for the disinfection of swimming pool water, the only drawback being its inability to control algae. With the consulting help of Dr. George Fitzgerald of the University of Wisconsin, who has furnished us with cultures of his selected resistant organisms, these studies are going forward using a variety of new approaches and studying a considerable number of compounds not hitherto used for this purpose.

Excessive eye burn was encountered when using iodine with an algicide whose base is phenyl mercuric acetate, and this has led us to undertake a definitive study of eye burn using both rabbits and a group of teenage volunteers. These studies are being carried out in the laboratory of the Eye Clinic of the J. Hillis Miller Health Center, and should provide long-needed quantitative data on this subject.

3 (c) Project Staff, March 1, 1967 - February 29, 1968

Professional	Period of Service	Time Basis
A. P. Black	March 1, 1967 - Feb. 29, 1968	50%
W. C. Thomas, Jr.	March 1, 1967 - Feb. 29, 1968	7.5%
R. P. Vogh	March 1, 1967 - Feb. 29, 1968	5%
Annie L. Smith	March 1, 1967 - March 31, 1967	100%
W. E. Harlan	March 1, 1967 - Feb. 29, 1968	5%
W. P. Bonner	March 1, 1967 - Aug. 30, 1967	100%
M. A. Keirn	April 1, 1967 - Feb. 29, 1968	100%
A. A. Jabero	March 1, 1967 - April 30, 1967	100%
J. J. Smith, Jr.	March 1, 1967 - Feb. 29, 1968	100%
H. Asano	March 1, 1967 - Dec. 31, 1967	100%
M. C. Jayaswal	March 1, 1967 - Feb. 29, 1968	5%
Egon Nordstrand	July 1, 1967 - Feb. 29, 1968	10%
Technical - Nonprofessional		
Walter F. Caldwell	May 1, 1967 - Aug. 30, 1967 Sept. 1, 1967 - Oct. 31, 1967 Nov. 1, 1967 - Feb. 29, 1968	100% 25% 12%
Pauline Gubbins	March 1, 1967 - May 31, 1967	100%
Virginia Morgan	March 1, 1967 - Feb. 29, 1968	50%
Secretarial		
Janice G. Larson	March 1, 1967 - Feb. 29, 1968	100%
Laboratory Assistants		
Albertha Pringley	March 1, 1967 - Feb. 29, 1968	50%

3 (d) Presentation of Papers, Publications and Degrees Awarded

1. "Iodine for the Disinfection of Water." A paper presented on June 5, 1967, at the Annual Conference AWWA, Atlantic City, N. J. A. P. Black, W. C. Thomas, Jr., R. N. Kinman, W. P. Bonner, M. A. Keirn, J. J. Smith, Jr., and A. A. Jabero.

2. "New Method for the Colorimetric Determination of Iodine and Free Chlorine Residuals in Water." Presented at the Annual Spring Meeting of the American Chemical Society, Miami Beach, Florida, in April, 1967. A. P. Black and G. P. Whittle.

3. "Resistance of Staphylococci to Halogens as Related to the Swimming Pool Environment." Presented on October 26, 1967, at the Annual Conference of the American Public Health Association, Miami Beach, Florida. M. A. Keirn and H. D. Putnam.

Papers published:

1. "New Methods for the Colorimetric Determination of Halogen Residuals. Part I. Iodine, Iodide and Iodate." A. P. Black and G. P. Whittle. Jour. AWWA, 59:471 (April 1967).

2. "New Methods for the Colorimetric Determination of Halogen Residuals. Part II. Free and Total Chlorine." A. P. Black and G. P. Whittle. Jour. AWWA, 59:607 (May 1967).

3. "A New Iodine Test." A. P. Black and G. P. Whittle. Swimming Pool Age, 41:46 (July 1967).

4. "New Colorimetric Methods for Halogen Residuals." A. P. Black and G. P. Whittle. Water and Sewage Works Reference Number - 1967, pp. 232-237 (Nov. 1967).

5. "Iodine for the Disinfection of Water." A. P.Black, W. C. Thomas, Jr., R. N. Kinman, W. P. Bonner, M. A. Keirn, J. J. Smith, Jr., and A. A. Jabero. Jour. AWWA, 60:69 (Jan. 1968).

Papers in press:

1. "A Case Study of the Pollution of Ground Water by Sewage and Industrial Wastes." A. P. Black, W. P. Bonner, J. J. Smith, Jr., M. A. Keirn, and R. P. Vogh. Submitted for publication in The Jour. of the Water Pollution Control Federation.

2. "Resistance of Staphlococci to Halogens as Related to the Swimming Pool Environment." M. A. Keirn and H. D. Putnam. Submitted for publication in Health Laboratory Science.